GODFREY

REPORT

ON THE SUBJECT OF INTRODUCING

PURE WATER

INTO THE

CITY OF BOSTON.

BY LOAMMI BALDWIN, ESQ.
CIVIL ENGINEER.

BOSTON:
JOHN H. EASTBURN, CITY PRINTER.
1834.

REPORT.

Charlestown, October 1, 1834.

Sir,

By your notes of May 7 and 10 in behalf of the Committee of the City Council, I am requested to make an examination, survey and report upon the subject of supplying the city of Boston with pure water, agreeably to a vote of the City Council, passed April 14th, 1834, which provides that a Committee be appointed "with authority to cause a survey to be made by competent persons for the purpose of ascertaining whether a steady and copious supply of pure and soft water can be obtained, and also what will be the best mode and the cost of introducing such supply of water into the city, and that the said Committee report to the City Council the result of the survey as soon as completed."

As you express a wish to have the survey so far completed as to enable the Committee to make a report of their proceedings to the City Council at an early period in the autumn, I present the result of my examination and survey for your consideration. It is as complete as the time and other engagements allowed me to make it, though far from being so full, definite, and so much in detail as the important object demands.

By the language of your commission it appears the City Council have in view only one mode of furnishing the town with water, and that is, by bringing it in from distant and abundant sources, either by canals, aqueducts and pipes, or by aid of pumps. But on reflecting much upon the enterprise, many other considerations intimately connected with it arose in the course of investigation that must have an important influence upon the main design which is the Health, Cleanliness, and comfort of the City.

There are four methods by which water is usually procured by the citizens of populous towns. *First*, by collecting in cisterns rain water falling on the roofs of houses, &c. *Second*, by raising it from wells made in the common way. *Third*, by boring into the earth and tapping springs below. *Fourth*, by conducting it into town from high and distant sources either by aqueducts, conduit pipes, or Pumps.

RAIN WATER RESERVED IN CISTERNS.

This mode of procuring good, soft water is often adopted in Boston and is more or less practised in all towns where no pure water can be obtained from the earth, and in some parts of the world no other fresh water can be had.

COMMON WELLS.

Where natural springs at the surface are not at hand this is the first artificial means of obtaining good water. From the porous nature of the upper strata of the earth this expedient sometimes fails and is often deceptive, even where the ground a little below the surface appears saturated with copious springs. This is because the absorbent quality of the top layers receive, before it can escape along the surface, most of the filthy water that has been used, together with other feculent liquids, which naturally filter through and mingle with lower veins of water and thus pollute that of wells situated in such soils.

ARTESIAN OR BORED WELLS.

The name of Artesian Wells, called in French, *puits artésiens*, is derived from that of Artois an old province of France, now within the department of *Pas-de-Calais*. It was in this district, that the practice of boring for water was first carried to great extent in former times, and where the nature of the ground and copious springs were uncommonly favourable to the operation. Hence this very convenient name for such works has been generally adopted in Europe and particularly on the continent. (1.)

Artesian wells have been made in Boston and the neighbourhood within a few years, but are by no means a very recent discovery. "The art of boring the earth for bringing up pure water to the surface has been the practice of ages. There are many reasons for believing it the invention of miners who have constantly occasion to use it in their works. Very small and deep wells are found in the East, called Greek wells, which could never have been executed without the aid of

(1) See notes at the end.

machines; and some Missionaries relate that the Chinese are very expert in the art of using the fountaineers' auger which they employ with success in all parts of that vast Empire." (2.)

The first evidence of applying artesian wells to the draining of land, bogs, and wet ground is found in Elkington on Draining, though it is stated in the work, that it has been practised in Germany. (3.) His plan is, where the bog or wet ground lies upon a bed or stratum of clay or other nonconducting material underlaid with sandy or porous strata, to bore through the impervious sheet, and allow the water to descend into the earth. In Chap. V. page 46 is found the description of his process.

In the Article before quoted from *Annales des Ponts et Chaussées* two or three novel and peculiar applications of such wells are given. The municipal council of St. Denis, near Paris, wishing to procure a supply of fresh water, from the known success of Artesian wells in that district, made a contract with the Engineers, Messrs. Flachat, who bored one near the Post house 203 feet deep (62 *mètres*) which produced from that depth more than 9,000 cubic feet, 71,000 gallons (270,000 *litres*) in 24 hours. In such cases the same supply is generally constant, and when the hydraulic pressure forces it above the surface it is impossible to check its flow; and here great mischief arose from the continual flooding of the street.

This serious inconvenience arrested the Council for some time in their preparations for sinking another in Flanders Square. But a remedy for the evil of streets inundated by water of a spouting fountain issuing from a depth of 203 feet below the surface was promptly furnished by Mullot, a distinguished Engineer employed in the environs of St. Denis who made a contract with the City "to sink again (*perdre*) in the earth the water of the well after it should be used for all the purposes for which it was procured."

Mr. Mullot's very curious method adopted for the new well, was formed upon his experience in making Artesian wells in the vicinity, and upon his science of the geological nature of the soil and strata. The following is a translation of its description.

"The new well was bored to the depth of 213 feet (65 *mètres*.) Like the first it traversed four sheets or veins of water. Within the well three concentric tubes were placed like those of a spy glass, but with this difference, that they did not rub against each other like those of the optical instrument, but were seperated from each other by a space of about 2 inches (0,054 *mètres.*) The water of the lowest sheet arose to the surface of the earth within the smallest of the three tubes; that of the vein situated at the depth of 180 feet (54.90 *mètres*) was received within the space between the smallest pipe and the middle one; and the third pipe enclosing the other two, received and discharged into the third sheet, which was not an ascending spring, all the water rising in the two interior tubes."

Many important advantages may be drawn from Mr. Mullot's ingenious plan and several illustrations of the cheapness of Artesian wells of his contrivance both in England and France are stated in the article referred to. Great facilities are offered by applying this method to the immediate discharge of foul or putrid water into the earth in the spot where it is received and employed, and a remarkable case is given at page 317 of the same number of Annales des Ponts et Chaussées.

In 1818 an establishment for making Potatoe Starch was begun at Villetaneuse, a village a league from St. Denis, situated in the fields, but not legally authorized before July 1822. It was at first on a small scale, but gradually increasing yearly, it became at last a manufactory, using daily about 20,000 gallons (80,000 *litres*). This water charged with vegetable matter and albumen, a peculiar animal substance and all other soluble materials of potatoes, flowed off by a small gutter more than a mile across the plain to Enghein brook and into the Seine. Sulphurated Hydrogen and other gases arising from Chemical action of the various matters held in solution, &c. was distinctly perceived along the drain or gutter and the brook below where the water of the starchery entered it, so that loud and numerous complaints arose among the neighbours, till at last the magistracy interposed, and forbid the manufacturer discharging the waste water into the brook or even into the gutter.

To silence these complaints the proprietor sunk wells in his own ground deep enough to enter the upper stratum of sand saturated with the water that supplied the common wells in the neighbourhood. Into these new sinks he discharged all the waste and refuse water. In consequence of this the complaints soon became more violent than ever, as the neighbours' wells like his own became corrupted, till the owner almost despaired of continuing his manufacture ; the council of health, in fact, leaving him no other alternative than "sinking the water into some subterranean current by means of wells or holes made by the fountaneers' auger." In this state of things he consulted Mr. Mullot, who readily engaged by contract to accomplish a remedy by means of boring and to fulfil two important conditions ; *First*, " to sink or lose (*perdre*) the dirty water of the starchery ; and *second*, to sink it in such a manner as not to injure the well of the Manufacturer, nor those of the neighbours at a short distance from the establishment."

The sounding was driven by the auger to a depth of 210 feet (64 *mètres*) in the Calcarious Chlorite, stopping a little above the point corresponding to the deepest sheet of the well in St. Denis Place. The different sheets or veins of water passed in boring, were perfectly isolated by cast iron pipes driven down with great force, that the outside should touch and bear hard, all the way, against the interior of the bored hole, so that the veins of water should have no communication with each other. The two conditions of the contract were fully complied with, to the satisfaction of the Proprietor and Engineer and 20,000 gallons have been daily sunk or *lost* through the well and absorbed at the lower end of the tube, ever since the discharge commenced. At the end of the winter of 1832 and 1833 after this singular drain had been in operation five months, receiving during that time all the refuse and feculent liquid of the starchery, some of the water, &c. was brought up from the bottom by a peculiar instrument used by miners having a valve at the lower end, and both manufacturer and engineer were astonished to find nothing but sand and whitish water.

Success so complete and extraordinary both as regards industry and health, soon made evident the benefits which might be drawn from the use of Artesian wells. A powerful company was immediately formed after the winter of 1832 and 1833, to apply them to draining of a totally new character, that of sinking all the foul water subsiding from the manure pits (*voiries*) of Paris, of which, there were two, one at Mont Faucon and the other in the Forest of Bondy 10 miles from the City.

The authors of the article in the Annales des Ponts et Chaussées, No. 157, give a striking example of the force of such springs which rise above the ground, quoted from another French work. It occurred in England about 3 miles from London.

" Mr. Brook of Hammersmith having bored in a garden to the depth of 360 feet 4½ inches diameter, obtained so copious a jet of water, that in a few hours the whole lot of ground on which the house had just been erected was filled with water; all the Kitchens and ground floors within an area of 300 feet round were filled with it also and the evil became so great that upon numerous complaints the magistrate was obliged to interpose, expressing fears that the houses would sink into the soil or have their foundations sapped. Two men attempted in vain to stop the pipe by driving in wooden plugs, but they were constantly rejected again. Another man repeated the trial, but all efforts were ineffectual. At last an engineer proposed to drive in several iron pipes with diameters successively diminishing, one within the other, and in this way the impetuous stream was stopped, which had created most lively apprehensions and threatened serious damages."

A favourable opportunity exists at Norfolk in Virginia for supplying that Borough by means of Artesian wells with an abundance of pure, fresh water, which the inhabitants do not enjoy, while nothing but bad water is taken from ordinary wells. The upper stratum of alluvial soil, characteristic of that part of the country, for the depth of 10, 12 or 14 feet in Norfolk, Portsmouth on the opposite side of the river, and the surrounding precincts, is composed of sand with some clayey mixture towards the surface, and in a fluid state at the under side. In this bed is found a quiescent source of good water furnishing a sufficient supply by common wells. But the soil is absorbent, and hence in the thickly settled parts of the town, the water is not good in consequence of the polluted water discharged on the ground and in streets sinking and mixing wlth the spring. Those, therefore, who can afford it, buy water throughout the year, brought from a well in the outskirts of the town. Many have cisterns and depend mostly on collected rain water. Next below, is a compact bed of marl with some shells, impervious to water. This is of variable thickness from 15 to 30 and 40 feet. The next vein under the marl, or the third stratum, is friable shell lime stone or calcarious tufa, which resisted the auger so much that it was worn smooth or often broken in boring one or two feet into it. This bed furnishes a powerful ascending spring of purest water, that rises in a hole bored through the marl to within about eight or ten feet of the surface of the ground.

At the Dry Dock lately built at the Navy Yard there, the depth of the vein of water is seventy feet below the top, at the foot of the Dock next the river, and about 45 or 50 feet at the head. It became necessary to drive the foundation piles to this bed where they stopped and afforded the only safe bearing for the work.

This spring is so powerful by its ascending hydraulic pressure, that after piles 30 feet long had been driven three or four days, the water made its appearance on the heads of most of them, arising through the pores of the piles, which were common pitch pine, (*Pinus Rigida*,) and stood in thin sheets with the upper surface flatly convex, often breaking over the edge and passing down the sides. Towards the head or upper end of the Dock, the marl was only 10 or 15 feet thick after the excavation was effected 40 feet deep. Here the marl was broken upwards in large flakes or sheets, and the spring discharged itself through the fissures. This gave regular employment to the steam engine that had been prepared for it, and when the foundation floor of masonry had been raised four or five feet, it became convenient to measure accurately the amount of water furnished from this vein, when it was found 10,000 cubic feet, or about 75,000 gallons in 24 hours. It rises to the height of 9 feet below the coping of the Dock, and its hydraulic effect upwards on the underside of the floor, between the turning gates and head, produces a pressure of more than 23,000 tons, and furnishes enough to water a Frigate in one day.

AQUEDUCTS, CONDUIT PIPES AND PUMPS.

ANCIENT ROME.

Before entering upon an exposition of the sources, routs, plans, &c. that have been considered for supplying the City of Boston with water, it seems requisite to give a sketch of several methods employed for similar purposes in other places or countries and in other times. As many such came into view while investigating what scheme should be recommended to the attention of your committee, it cannot be unacceptable to the citizens at large, who are all interested in the inquiry, to know something of the simple, successful, or magnificent projects adopted elsewhere.

The most authentic accounts we have of a copious supply of water in towns among the ancients, are those of aqueducts built by the Romans for conducting water to Rome. All data for the following tables are drawn from Rondelet's translation into French of the Latin work written by Frontinus, who died A. D. 101, and who had for several years the whole superintendence of the Roman aqueducts and of the management and distribution of the water flowing in them to the city (4.)

In the following table is placed, *First*, the name of the water or aqueduct; in the *Second* column the era of its construction; and the *Third* the length of each aqueduct in miles and decimals; in the *Fourth* the cubic feet discharged in 24 hours, and in the *Fifth* column the gallons in wine measure

NAME.	Era.	Length.	Cubic feet.	Gallons.
1. Appian Aqueduct,	B. C. 312	10,3250	3706575	27,724,181
2. Old Anio "	" 273	36,6775	8932338	66,813,887
3. Marcian "	" 146	56,9417	9525390	71,249,917
4. Tepulan "	" 127 }	14,2341	{ 903795	6,760,386
5. Julian "	" 35 }		{ 2449386	18,321,407
6. Virgin "	" 22	14,3116	5085624	38,040,467
7. Alsietina "	A. D. 14	20,4526	796152	5,656,016
8. Claudian "	" 49	42,1989	9356817	96,988,991
9. New Anio "	" 90	54,1644	9622878	71,979,127
		249,3058	50,378,955	376,834,379

In the *Notions Prèliminaires* prefixed to his translation, Rondelet remarks, page 20. " It appears from this, that the water furnished by the nine aqueducts of Rome described by Frontinus, would be equal to a river 30 feet wide and 6 feet deep, flowing with the velocity of 30 inches a second, that is, with a velocity equal to that of the Seine in its ordinary height." These are French measures given by Rondelet, but reduced to English, the velocity would be nearly 32 inches a second.

Some auxiliary supplies or feeders make the total length of the Roman aqueducts exceed 255 miles, all of which were built of stone and covered either by arches or large flat stones. The works consisted of three modes of construction. *First*, of subteranean aqueducts, or so placed as to be wholly covered with earth when the ground admitted it, or when high land required deep excavation. *Second*, on substructions, where the surface was too low for the level or slope. In these places a solid mass of stone work was raised to a sufficient height to build the aqueduct upon, where in modern works earth embankments would be substituted for masonry; and *Third* where it was to be conducted over streams of water and deep vallies or ravines, the aqueducts were elevated on stone bridges, built on arches, in some cases on two or three rows of arches one above another. In the 255 miles there were 191 of the first, 42 of the second and 22 miles of the third kind of construction.

MODERN ROME.

Rome is now supplied with water by three aqueducts, being three of the ancient works restored in modern times.

First *Aqua Virgini*, called by Frontinus Aqua Virgo, denominated in the above table Virgin Aqueduct. The trunk of the aqueduct having been injured, the reparation was begun under the Pontificate of Nicholas V. and Sextus IV. and completed under that of Pius IV, in 1568. This water supplies the beautiful fountain Trevi, thus named from the three discharges issuing from it, or from its being placed at the junction of three streets. The water this aqueduct furnishes is 2,322,762 cubic feet daily, discharging through 7 principal conduits, at 13 public and 37 other fountains.(5)

Second, *Aqua Felice*. This is a part of the ancient water of the Claudian and Marcian aqueducts united with many others, and collected under Sextus V. The daily quantity it furnishes is 727,161 cubic feet, which supplies 16 public and 11 other fountains. The Moses fountain discharges from this source.

The Pauline aqueduct, called *Aqua Paola*, is the third of the ancient works restored. The water is collected within the territories of Arcolo and Bassano, and conducted along the ancient aqueduct of Alsietina. This was effected under Pope Pius V. and directed by Charles Fontana, an eminent Hydraulic Architect, who constructed the great fountain of *S. Pietro-in-Montorio*. Additional water was also taken from Lake Bracciano by Fontana in 1694, under Clement X. The whole quantity in 24 hours is 3,325,531 cubic feet, about one third of which goes to feed the fountains of St. Peters, and those of the Pontifical Palace on the Vatican Hill; the rest is distributed among 8 public and 23 other fountains, as well as to 21 work-shops, (*usines*) in St. Pancras street. All three aqueducts now give 6,375,455 cubic feet in 24 hours, equal to 49,688,403 gallons.

An evidence of the durability of these old Roman structures is furnished in this junction of water from Lake Bracciano by Cardinal Orsini, under authority of Clement X., upon condition that a part of the water should be used to feed a second fountain about to be built in St. Peter's Square at Rome and the rest to be divided between the Apostolic Chamber and the House of Orsini. From the lake the conduit leads to the old Alsietina aqueduct in which it flows 20 miles to the city and it was found to be in so perfect a state when the trial was first made after the restoration, October 13, 1693, that all the water which entered the old aqueduct was discharged at Rome without any loss, after its use had been suspended nearly 1000 years.

It is unnecessary to refer to more of the great and splendid structures of this nature built by the Romans in various places, or by modern nations in Europe. But those erected by the Romans near Constantinople and that at Lyons in France deserve notice for their singular character.

CONSTANTINOPLE.

Three aqueducts exist in the valley of Bourgas 8 miles from Constantinople, for conducting water into the city. One of them is remarkable for the beautiful architectural arrangement and the solidity of its construction. It is 115 feet high and was built under the Emperor Justinian, A. D. 527.

These aqueducts are in some parts unlike those of Rome, which were formed on a continuous line for many miles with a regular slope from the source to the city, but are interrupted by reversed syphons. Instead of crossing deep and wide vallies in the usual manner of stone structures, the aqueduct terminates on one bank in a reservoir or cistern and a pipe is laid from it down the sloping side of the hill to a stone pier erected at a suitable distance; the pipe rises up the pier to the top where the water from the reservoir is discharged into a small cistern nearly as high as that in the reservoir. From the cistern, another conduit pipe descends to the bottom of the pier, passes along the ground to a second pier at a proper distance and rises to another cistern on the second pier, and so on till it rises on the crest of the opposite bank, where the water resumes its regular motion along the aqueduct. Owing to friction in the pipes, some loss of head occurs, but the principal reason for adopting this expedient was the saving expense in building a high stone arched way or bridge with two or more rows of arcades to preserve a regular flow of water on a sloping plane. These piers are called *Souterazi*, which may be dispensed with in future works and the pipes laid down one side, across the bottom, up the other side of the valley and the continuous motion of the water preserved without any sudden angles.

ANCIENT AQUEDUCTS AT LYONS.

"Nothing can give a better idea of the splendor of the city of Lyons under the first Roman Emperors than the ruins of its ancient monuments. Here are still observed the remains of temples, palaces, amphitheatres, basins for exhibiting sea fights, baths, and of many aqueducts, three of which were constructed under Augustus, Tiberius and Claudius for supplying water to that part of the city situated on the Hill."(6)

AQUEDUCT OF MOUNT PILA.

This was built by Claudius, who was born at Lyons, to conduct water to the Emperor's Palace, situated on the highest part of the city. It was 34½ miles long. There were 13 bridges of stone to support the aqueduct over rivers or deep vallies, two of which were crossed by leaden pipes laid down the sloping ground on one side, crossing the valley and resting on the opposite bank. This is called by Rondelet, Syphon Bridge, (*Pont-a-Syphon*). A foundation in masonry was laid on a regular slope, part of the way on arches, from the termination of the aqueduct on the top of the hill, to the end of the Stone Bridge crossing the bottom of the valley. The bridge was about 40 feet high and the perpendicular height of the aqueduct above it was 140 feet. Nine leaden pipes of about 8 inches interior diameter and 1 inch thick were laid upon the surface of this inclined plane, on the bridge across the valley and on a corresponding, ascending plane on the other side, and thus a communication was opened between the two opposite crests of the valley.

It has often been said that the Romans were ignorant of the hydraulic principle that water would rise in pipes &c. to the same level as the source when unobstructed. But the same charge of ignorance may be made against the moderns within the last two centuries with equal justice, if we judge from the works constructed under Louis 14th, for bringing water to Versailles ; from the aqueduct of Montpelier built in 1752 ; from that of Casertes near Naples built in 1753 ; and from numerous other modern works.

I notice this ancient monument to shew that a Syphon Bridge erected nearly 1800 years ago by the Romans is a model that may be judiciously applied perhaps in some circumstances for an aqueduct to supply the town of Boston.(7)

LONDON.

The quantity of water supplied to London is immense and nearly half of it by pumps and steam engines. The new river water is brought in an open canal about 40 miles and embraces two sources, one from a spring at Chadwell, between Hertford and Ware 21 miles north of London ; the other from an arm of the river Lea, whose source is near the Chadwell spring, in proportion of two thirds from the former and one third from the latter supply. The following tabular statement of water furnished to the city from incorporated companies is taken from a report made to the King in 1828 by commissioners appointed by him for that purpose, as given by Mr Williams in his work on *Sub-ways* of London. (8)

The 5 first on the list are on the north side or left bank of the Thames and the 3 last on the right bank. The names of the Companies and number of houses or tenants are given in the two first columns and the quantity in cubic feet and gallons stated in the two last columns are those presented in the report.

TABLE OF WATER COMPANIES FOR LONDON.

NAMES OF COMPANIES.	Houses or Tenants.	Cubic feet per day.	Gallons per day.
1. The New River Company by Canal,	66,000	2,000,000	13,000,000
2. The East London Water Works,	42,000	950,000	6,000,000
3. The West Middlesex "	15,000	360,000	2,250,000
4. The Chelsea "	12,400	282,000	1,760,000
5. The Grand Junction "	7,700	450,000	2,800,000
6. The Lambeth "	16,000	200,000	1,244,000
7. The Vauxhall South London "	10,000	160,000	1,000,000
8. The Southwalk "	7,000	115,000	720,000
TOTAL,	176,100	4,517,000	28,774,000

Among the above named corporations, the New River Company furnishes the most. It gives a mean of 197 gallons to a house daily. Taking the number of persons in a house at 7 it is 28 gallons to each, and at 5, nearly 40 gallons to each individual. In fact this aqueduct or canal supplies nearly half the water brought into London and the district is better served than any in the City. All the other seven companies supply water wholly from the Thames by pumps, have 13 reservoirs, 21 steam engines of the aggregate power of 1,340 horses, and give an average of a little over 143 gallons to a house or tenant, which, supposing 5 inmates to a house is equal nearly to 29 gallons to a person, or over 20 to each where 7 constitute the family.

Taking the eight watering establishments together, they give a mean of about 163½ gallons to a house or tenant; and if each had 7 in the family, then about 23 gallons; if 6, 27 and if 5, 33 gallons to each person. Upon the supposition that 6 is the fair average number for each house or tenant, as set down in the table made up from the Parliamentary report, it results that the population furnished with water by incorporated companies is 858,600. But this is wild conjecture. Many set down as tenants, are owners and pay for several houses, sometimes a whole street; besides, the English are a cleanly people and use water very copiously for all personal and domestic purposes; and although not a public fountain and rarely a private one is met with in London, a vast quantity of water must be employed in manufactures, mechanic trades, markets, stables, gardens, &c. which far surpasses the proportion due to the number of people supposed attached to each house or tenement by the foregoing estimate.

Applying the same form of illustration which Rondelet presented of the enormous quantity thrown into Rome by her 9 aqueducts, the 8 London works deliver a column of water equal a river 30 feet wide and 6 feet deep, English measure, flowing at about the rate of 3½ inches a second; or otherwise, the latter compared with the former would be as 1 to 11 nearly. It would fill a reservoir as big as Boston Common 2 feet 4 inches daily and that delivered in Ancient Rome would fill it to the depth of 25 feet 8 inches. What is now furnished to Modern Rome by her three aqueducts would, in 24 hours, fill the reservoir 3 feet 3 inches, while an ample supply for Boston of 5 million gallons—668,450 cubic feet would cover the Common daily 4 inches only.

EDINBURG.

A new supply of water was attempted for Edinburg a few years ago under direction of James Jardine, Esq, an eminent Engineer of the city, and while I was there in the summer of 1823 the works were in progress, but unfortunately I had not an opportunity of seeing Mr. Jardine. I had the pleasure of accompanying a friend from Boston to view the works, about 10 miles from Edinburg. The water was collected by underdraining in various directions in the deep gravelly soil of the valley of Glencross Burn, about 9 miles from the city. A small brook or burn runs down the valley and the water passed to and turned some miles lower down the stream. Instead of taking the water of the burn immediately into pipes, the process was adopted of digging trenches and collecting it from beneath the surface into a basin or cistern, covered with a neat stone building, and from the cistern the water entered the pipes and thus was conducted to Edinburg. Trenches 10, 12 or 15 feet deep were dug in a bed of loose gravel abounding in purest spring water. Stone drains were then made about 2 feet wide, the sides laid up in dry stone rubble walls 4 or 5 feet high and covered with large flat stones and then filled over with the porous earth which came from the trenches.

Workmen were engaged on some of these when we visited the place, and one cistern if not the only one, was completed, into which a beautiful stream of clear water was running but passing to waste again because the line of pipes were not all laid. To satisfy the millers against injury from this underground encroachment of their right, it became necessary to provide a supply to compensate their loss, and a reservoir was provided by a dam across the burn and the valley, which I saw raised only about half the intended height.

The spot where the work is situated is called Crawley Springs and on the burn, about a mile above the dam is Habbies Howe the scene of Ramsay's pastoral — The Gentle Shepherd. I give the following particulars from minutes furnished by my brother George R. Baldwin, who had them from the Engineer in 1832.

Boston, June 8, 1834.

" Dear Brother,

I have referred to my memoranda kept while in England and Scotland, relative to the Edinburg Water Works, and find the following account to be the substance of what I then recorded.

" Mr. James Jardine Engineer of the water works at Edinburg, informs me that the water brought from the country for the use of the City, is collected by digging trenches or ditches along the sides of hills to intercept the springs. These ditches terminate in one or more reservoirs, from which the water is conducted to the City in a cast-iron main, that drops 300 feet below the fountain-head, or surface of the reservoir. The main at the reservoir is about 20 inches in diameter, and at the lowest place between that and the City, it may be about 15 inches, (the smallest diameter of the main) and 1¼ inches in thickness. The pipes were all proved to support a column of water 800 feet high, under which pressure none were broken, except one supposed to have been cracked while on its way from England.

"The compensation-dam on one of the branches or burns of the river, which would have received the water taken for the use of the City, was built of earth in the following manner. Across the valley of the burn, an excavation was made 52 feet deep, and say 480 feet in width at the lowest place; this was filled with good embankment-earth, having a puddle-ditch of clay 60 feet wide at bottom, brought up with it, running across the valley below the middle of the excavation. On this base the embankment was carried up together with the puddle-ditch 75 feet above the level of the burn, the embankment having a slope of 4 to 1 on the up-stream, and 2 to 1 on the down-stream side of the dam. The puddle-filling was regularly diminished from its base in the excavation to the top of the embankment, where it had a breadth of 30 feet, and occupied the whole top. The slope above the puddle-ditch was made by depositing from waggons layers of earth one foot thick, well puddled down in succession."

"The reason Mr. Jardine gave for digging so deep into the valley of the burn was, that the natural soil being so loose a texture it was not considered safe to base the embankment at a higher level.

"At the level of the burn, a cast-iron pipe was laid through the puddle-ditch, terminating at each end in stone culverts; the up-stream one being 3 feet in diameter, the other 6 feet high and 4½ feet wide, having an oval form for its section; at the other end of the pipe are flanch-cocks for drawing off the water for the use of the mills below. At a higher level in the dam, is another culvert for taking off the water, and at one end of the dam through a rock the water is allowed to run off and fall in a cascade to the burn below.

The water conducted in this aqueduct to Edinburg is collected from pure native springs far beneath the surface of the ground; it passes in this manner to the covered reservoir, hence in iron pipes 9 miles to the City, and throughout its passage is never exposed to the weather, or even to the light, until drawn for use at Edinburg. From these circumstances, it constitutes, probably, the purest artificial supply in existence, for the domestic use of a town.

Mr. J. Wright, in his memoir to the Commissioners appointed to inquire into the state of the supply of water to London, published in the Parliamentary reports for 1828, says, after referring to Rome, Paris, &c.

"To look, nearer home. The City of Edinburgh receives a supply of excellent water from a distance of eight or ten miles. Under the able direction of the late Mr. Rennie, Mr. Telford, and Mr. Jardine, and at an expense of only £175,000, the most magnificent works of the kind in Great Britain have been completed. The water is excellent; and the quantity to an inhabitant is nineteen gallons per day; and not less than 280,000 gallons are daily permitted to run to waste. In real utility, they rival the boastful aqueducts of ancient Rome, and are the admiration of all scientific strangers."

GREENOCK.

A very interesting and extensive establishment, called the Shaws Water-works, has been effected since 1824, at Greenock on the Clyde, which arose from researches for supplying the town with water. Before the operation of this plan, Greenock was badly furnished, and what was used for domestic purposes was brought on carriages from a distance. To remedy this evil, many surveys were made by different engineers, without effect, when Sir Michael Shaw Stewart employed Mr. Robert Thom, an engineer, who, in 1824, explored the environs of Greenock, and found that not only an ample supply for the uses of the City could be obtained, but also enough to create a water-power for mills equal to all the steam-power then used at Greenock and its vicinity. (9.)

The principal source is in a stream called Shaw's Water, which, with other small tributary streams, fills the great reservoir of 296.73 acres, containing 284,678,550 cubic feet of water. The compensation-reservoir has an area of 40.53 acres, and contains 14,465,898 cubic feet. Six auxiliary reservoirs, the main feeder, and other parts of the works, make tbe whole amount retained in reservoirs, contemplated in their unfinished state in 1829, to be 600,000,000 cubic feet of water, and from the experience of the two preceding years, the amount in reserve was above 700 million of feet. The area of the reservoir, feeder, &c. is more than 396 acres.

Mr. Thom's calculation was, that the inhabitants of Greenock were 25,000 souls, and to allow 2 cubic feet, making 14.96, or nearly 15 wine gallons daily to each, or 18,250,000 annually for the town of Greenock. For mills and manufactories the provision was 1,200 cubic feet of water a minute during 12 hours each day, and for 310 days in the year, on two separate lines of supply, thus making the total consumption for hydraulic power, 565,680,000 feet.

The principal feeder is quite circuitous, and between 6 and 7 miles long. It conducts the water to a regulating-reservoir on the hill behind Greenock, where the water is 513 feet above the Clyde at high water. From the reservoir the water is discharged into two lines of mill-sites, one falling into the Clyde on the east, and the other on the west side of the town. The whole fall on the west line is 513 feet divided into 18 mill-pow-powers, which gives a mean of 28 feet 5 inches for each. But on account of the peculiar character of the ground, I presume, the falls are not all equal. There is one 43 feet 6 inches, one 42, one 15 feet, the last on the line. They are nearly all from 25 to 30 feet. The same variable fall exists at the mills on the east line, where there are 19 sites in a fall of 512 feet 4 inches, giving a mean of 26 feet 11 inches.

The whole work has been put into the hands of a company by act of Parliament, who have sold out mill-privileges, and engage to furnish 1,200 cubic feet a minute. The water passes through the first mill, and runs to the second, from the second to the third, and so down each line of mills. If any intermediate mill or mills stop, the water still passes on to those below. Mr. Thom estimates 1,200 cubic feet of water falling 30 feet as equivalent, in mechanical force, to one of Bolton & Watt's steam-engine of 54 horse-power.

All the contrivances of Mr. Thom are ingenious for regulating the discharges of the reservoir and the supply for the mills, which is done by self-acting gates or valves. The whole system shows an admirable combination of hydraulie science and engineering skill, perhaps never so well exemplified in any other work. But the most original and ingenious expedient was his method of constructing filters upon a large scale for purifying the water for the ordinary domestic use of the inhabitants. He constructed three, each 50 feet long, 12 wide, and 8 deep. All filters, however, fill and choke so much, that after a short time they cease to transmit any water, and become useless, unless the sand is cleaned or removed. To remedy this evil, he constructed them so that when the sand became filled with the sediment, the passage of water through it is reversed, and thus all the impurities and sediment, consequent upon the process of filtering, are immediately washed out and discharged through a waste drain for that purpose. This operates completely, and is the first instance of the kind. After the sand becomes again clean by sending the water through it in a contrary direction for a few hours, the filter is restored to its ordinary functions in the usual way.

Mr. Thom closes a letter to Sir Michael Shaw Stewart, March 20, 1829, upon the subject of the filters, as follows ;

" You are also aware that the medium through which the water flows has been composed in such a way as to remove all the colouring matter of bog (*marécaguese*) water, and other similar impurities held in solution, and that in this respect we have also completely succeeded ; but as the substance employed for this purpose is expensive and in time becomes saturated and requires being taken out and replaced by new, great care has been taken to prevent as far as possible the entrance of such water to the filters."

" Upon the whole, a filter without the means of removing the sediment deposited by the water, cannot furnish for any considerable time a uniform supply of pure water. In fact, by giving a great surface to the filter, that is, to the surface of the sand or gravel with which the water comes into contact ; in giving to the bed great thickness ; in arranging the strata of materials so that the gravel or coarser sand shall be at the top, and employing finer and finer sand as we approach the cistern where the pure water is received, there is no doubt we can construct a filter to operate for a proportionally longer time ; but still unless such an arrangement is made that the foreign matter deposited by the water can be removed, the action of the filter will gradually be lessened and finally cease."

" As to the expense of the new system of filters, which I propose, it will depend much upon the localities, on the quality of water before filtering, on the more or less favourable situations in which they may be disposed, on the price and distance of the materials to be used. In some circumstances the construction of filters will cost double of those other situations might require, and the same filter may furnish more or less, according to the purity of the water to be filtered and the kind of sediment held in solution.

" In favourable situations these self cleansing filters may be so established as to supply a population of 25,000 inhabitants, with 2 cubic feet daily to each for *three hundred pounds sterling*." (10.)

GLASGOW.

The water works of this city deserve notice on account of the late Mr. Watt's ingenious method of laying cast iron conduit pipes across the bed of the Clyde. The town is situated on the right bank which is clay, while the left bank is composed of pure fine sand. I take the following extract of a letter from Mr. John Robison to Dr. Brewster, dated April 1820 — it is published in the 3d vol. of the Edinburg Philosophical Journal, with a plate shewing the mode of uniting and laying the main.

" The Glasgow Water-Works Company derive their supply of water from a well and tunnel formed in a stratum on the left bank of the Clyde, which affords a natural filter* for the water of the river. As the City lies on the right bank the conveyance of the filtered water across the stream was a problem of some difficulty. The fertile genius of Mr. Watt, however, enabled him to solve it.

" He suggested that a flexible iron main should be drawn across the bed of the river, through which pumping engines on the north side should raise the water from the well on the South side. In executing this plan, the well and tunnel were dug in the sand near the water's edge. The well is 10 feet in diameter and its bottom is 12 feet under the ordinary surface of the river, the feeding tunnel is 3 feet wide and 6 feet high, and extends for a considerable distance into the sand bank ; the well has a wooden platform bottom ; its sides and those of the tunnel are built of granite, put together without mortar, and backed with gravel, to prevent the influx of sand. The south end of the section pipe (or main) is turned down into the well to a sufficient depth. That part of it which lies in the bed of the river, is formed of pieces of 9 feet long (exclusive of joints) and 15 inches interior diameter. Part of the joints are formed in the usual way, but others are something like what is called " *ball and socket*" or " *universal joint*."

The whole is laid on strong frames made of parallel logs ; these frames are joined by strong hinges, having their pivots in horizontal lines at right angles to the axis of the pipes, and passing through the centres of spheres, of which the zones of the sockets are portions. The flexible joints are at the extremities of the frames.

" The frames and pipes were put together in succession on the south side of the river, and (the open or north end being plugged) were hauled into and across the bed in a trench prepared for them. The machinery for hauling them was of course on the north side ; the operation was aided and directed by pontoons, &c. The moveable joints of the pipes and hinges of the frames, allowed them to assume the form of the bed.

" Upon the plugged end emerging from the water on the north side, it was immediately opened and connected with the main leading to the pump to secure it against accidents from floods. There is a contrivance for removing any sand which may accumulate in the pipe. That part which is under water is covered over with stones and gravel, to protect it from injury from passing vessels.

" The demand for water having increased beyond expectation since 1810 (when this work was completed) a second main of 18 inches diameter, similar in all respects to the first, has since been added.

" At present the consumption of water is reckoned about 8,000 tons per diem. The Company's establishment of Engines is two of 36 inches cylinder and 7 feet stroke, and one of 54 inch cylinder and 8 feet stroke. These are employed in raising the water from the filter to the reservoir for distribution ; but as some parts of the City lie 150 feet above the level of the river, there are two smaller engines for forcing water from the general reservoir to one still higher to supply these places."

Assuming the population of Glasgow to be 60,000, the 8,000 tons of water daily from the pumps would be equal to about 37 gallons for each. The scheme of making a natural filter on one side of the river and pumping the water from the other was a very good expedient, but seems to have met with the objections incident to artificial filters. The deposition of the abundant sediment in the Clyde waters, has already lessened the supply of clear water to an alarming degree, and several attempts to increase the quantity of filtered Clyde water have entirely failed. Mr. Watt was consulted, who recommended the making more wells and tunnels in the same bank nearly surrounded by the river, which was done and the plan succeeded for a while and the inhabitants received a supply of excellent water. But it gradually decreased so that at the end of some years, they were obliged to take directly from the river.

In the summer of 1828, Mr Thom visited the works and speaking of them he says "I advised the extension of the wells and galleries along the sand banks near the River in the manner originally proposed by Mr Watt, which they have done, and the supply of pure water has since greatly increased ; but there is no doubt that in the course of a few years, in consequence of the sand being choked with sediment, the product will gradually diminish so much that other means must be resorted to for a necessary supply of pure water."

PARIS.

Water was brought into Paris by the Romans, under the emperor Julian A. D. 360, by an aqueduct above 9 miles and a half long, which was all under ground, except the stone arcade over a brook and deep valley at Arcueil. It conveyed water to the palace and hot baths, but was destroyed by the Normans, and after its use had been suspended 800 years, a new and beautiful arched aqueduct was erected by the side of the ruins of the old one, and its final restoration to public use was completed in 1634.

Other water works were also erected under Louis XIV, and in subsequent reigns, most of which have been removed, except the Pumps and steam Engines constructed at the two Chaliot water works on the right and left banks of the Seine.

The great and only considerable undertaking for supplying the city is the Ourcq Canal, which has been nearly twenty years in completing. It affords an abundant supply. The canal begins at the River Ourcq above 58 miles from Paris, and in its course takes in five or six other streams or feeders. The trunk of the Canal is 36.08 feet (11 *mètres*) wide ; depth 8.20 feet (2.50 *mètres*) depth of water 4.92 feet (1.50 *mètre*) and slope of the banks 1,50 base to 1 rise. The velocity of the water is calculated to be nearly 13 inches a second, and the slope of the Canal about 3½ inches a mile.

It terminates in a large basin near the Barriere of Villette. From the S. West corner opens the St. Martin Canal, communicating with the Seine on the East side of Paris and a short distance before coming to the basin the St. Denis

Canal is opened passing down to the Seine near that city on the north side of Paris.

At the north-west corner of the Basin is taken out the water for supplying the City by a subterranean canal or aqueduct, on the north side of Paris, (*aquéduc de ceinture*) nearly two miles and three quarters long. The work is in stone masonry, and the canal for the water is 3 feet 3 inches wide at bottom, 5 feet 3 inches deep, and 4 feet 6 inches wide at top. On one side is an off-set 4 inches wide, and on the other a foot-walk 1 foot 6 inches wide, making the whole breadth between the side walls above the trunk 6 feet 4 inches. These walls rise 4 feet 6 inches covered with a semi-circular arch. At various points there are galleries and staircases to descend to the subterranean aqueduct. I descended to examine the work with M. Girard the Engineer, by a flight of steps from the cellar of a house where one of the guardians resided.

Convenient arched passages are constructed under three principal streets where one may walk, and where are laid the different mains taking water from the aqueduct to conduct it to the various fountains and other points for distribution. They are laid upon stone blocks or cast iron frames, so that they may be easily examined all round from one end to the other. The beautiful fountain in the Garden of the Palais Royal, that in the Boulevard of Bondy, &c. are supplied from this water.

The Canal is estimated by Mr. P. S. Girard, the Engineer who constructed it, and had the whole superintendence of distributing the water in Paris, at 4,000 inches of water (*pouce d'eau de fontainier.*) An inch of water is so much as will flow through a hole 1 inch diameter, French measure, in a minute, under a head of 7-12 of an inch above the centre of the aperture, and is equal to 813½ cubic inches in a minute, or, 678 cubic feet in 24 hours, amounting to 2,711,680 feet for the 4,000 inches daily, or over 20 million gallons.

" The quantity of water necessary for a given number of inhabitants has not been accurately fixed. In France it has been generally estimated at 19195 *litres* (1 inch) for 1,000 inhabitants. The Scotch Engineers do not consider the supply complete at less than 9 gallons a day for each individual in a city. If we compare the distribution of water in London with the population, the supply is at the rate of 20 gallons for each person. But there are no public fountains in that city and the people receive no water but what is furnished by independent companies. At Paris 4,000 inches of water of Ourcq are appropriated for fountains and for cleaning streets, so that water is raised from the Seine for domestic use. The actual quantity thus used does not exceed 200 inches," (equal 135,584 cubic feet daily) "and it costs from an accurate and detailed estimate, the enormous sum of 4,265,756 francs," equal to $767,836. To supply the want of Seine water, on account of its cost, pumps are employed in nearly all private houses, and spring and well water is used, although it does not possess the qualities suitable for mechanical industry." (11.)

Great inconvenience arises among engineers and hydraulicians from the want of a standard unit to denote the quantity of water flowing in a given time. The fountaineer's inch (*pouce d' eau de fontainier*) is used by all French writers upon the subject, though admitted by most of them to be very indefinite. It is perhaps sufficiently correct for practical purposes, but not adopted in philosophical investigation. Genieys says, it is "equal the quantity of water a pipe an inch in diameter would furnish in a minute, so placed that the centre of orifice should be seven lines below the surface of the reservoir to which it is adapted. To estimate the quantity it is still necessary to determine the length of the pipe or thickness of the side of the vessel in which the aperture is made, through which the water is discharged. Now this has never been done in such a way as that all agree upon the exact amount; but it is generally admitted to be equal to 15 pints, or 13.33 litres a minute, or 19195 litres in 24 hours."

The above are French measures. The *litre* is equivalent to 61,028 cubic inches; hence the fountaineer's inch is 813½ cubic inches a minute, or 678 cubic feet a day. Gallon, as used by English writers is also a very ambiguous term, when applied to hydraulic discharges. The gallon, which I employ in this report,=231 cubic inches; the beer gallon,=282; and the imperial gallon,=277, 274 cubic inches.

Mr. Geniey's statement is that 19195 litres (one inch) is generally estimated in France, as a supply for 1000 inhabitants; which gives 0.6779 cubic feet, or a little over 5 gallons to each daily. Seine water is distributed by carriers in hogsheads or carts, for which they pay at the pumps or filters 6305 francs the inch, and retail again to the inhabitants for 30462 francs. The amount thus paid by the Parisians is annually 2,864,504 francs. Another class of water-carriers are those who carry it in buckets, (*Porteurs d' eau à bretelles*) hung to straps connected with a kind of yoke over the shoulders. These take water gratuitously from fountains of the second class, from the Seine, or from the filtering establishments on the quay of the Célestins, and sell it for 10 centimes the *voire*, or two pailfuls of water; about two cents for 4½ gallons. In this manner the water-porters receive 1,405,252 francs, thus making the total sum of 4,266,756 francs, = $767,836, as before stated, paid annually by the citizens of Paris for a daily supply of 135,584 cubic feet, or 1,013,168 gallons. Mr. Jenieys says " a company might furnish for domestic use ten times the quantity for the same cost."

BEZIERS.

In the 2d vol. of Annales des Ponts et Chaussés, page 157, Mr. Maffre, an engineer des Ponts et Chaussées, has given a detailed account of an examination and experiments made to prove the capacity and effect of a new steam-engine for raising water from the river Orb, to supply the town of Beziers in the south of France, near the Languedoc canal. The machine was intended as a substitute for an old and inefficient one, and was made and erected by Mr. Cordier, a locksmith of the town. He engaged to furnish to the basin in Saint Louis Place 18 inches of water for 14 hours a day. Thence by two conduits are supplies furnished to several fountains and basins in the town.

The horizontal distance between the suction pipe at the surface of the river and the axis of the pedestal, on the top of which is a little box or cistern, is 373 feet, (113.7 *mètres.*) The top of the pedestal is 224.15 feet (68.34 *mètres*) above the level of the Orb. The ascending pipe is $4\frac{4}{5}$ inches interior diameter, with the lower third part of its length $1\frac{1}{10}$ inch thick; the second third, $\frac{80}{100}$; and the upper third part of the length, $\frac{55}{100}$ of an inch in thickness.

On the top of the pedestal is a small copper cistern 24 inches long, 20 wide, and 15 inches deep. Into the bottom of the cistern or box opens the ascending pipe from the pumps, and from it also descends another pipe 20 feet; thence a horizontal pipe passes 225 feet to the centre of the basin in St. Louis Square, where it is turned up, by which the water issues from the cistern on the top of the pedestal, in the form of a low mushroom jet, rising constantly to the same height of 16½ inches.

The whole quantity during the day is 18 *pouces d' eau*, or inches during 14 hours, equal to 7,119 cubic feet, or 53,257 gallons. The cost of the engine house, machine, pumps, pipes, basins, &c. exclusive of the fountains, was 96,678 francs, $17,402. All pipes in the town are of pottery, and the annual expense of the works is 11,074 francs,=$1,993.

The whole maintenance of the water-works is supported by the inhabitants of Beziers, and all the water is discharged at 11 public fountains. Mr. Maffre found by experiment that the supply exceeded 18 inches, and that the contractor had fully complied with his engagements in all respects. He recommends that the machine should act more than 14 hours a day, and says that the quantity may equal 22 inches daily. He also states that half the expense of the establishment can easily be defrayed by selling water to the citizens for domestic uses, &c. as is done in other places.

This is another instance of the prevailing taste in France and other places on the Continent for fountains and public display of copious and convenient sources of water. In England and this country this rich and highly useful embellishment of towns is wholly neglected.

PHILADELPHIA.

The beautiful system of water-works erected at Fairmount on the Schuylkill near Philadelphia for supplying water to the City by hydraulic power, stands unrivalled, perhaps, for its simplicity, economy and effect. It was almost wholly owing to the ingenuity, perseverance, prudence and good sense of Frederick Graff, Esq. who is, and for many years has been, superintendent of the water-works. Many of the annual reports have recently been put into my hands, by the kindness of one of the City Council, Joseph R. Chandler, Esq. and from the last in the file, for 1832, I shall present an interesting account, drawn from the tables, shewing in detail the various objects, uses, and institutions, to which the Schuylkill water is furnished, with the water rents for each during the year 1831.

In the report for 1831, made January 12, 1832, Mr. Graff, the Superintendent, has inserted an extremely valuable document in the appendix, being a condensed abstract of the origin and progress of the works and gradual change into their present improved state, to 1832, which I shall take from the report.

"MEMORANDUM
OF VARIOUS PARTS OF THE WORKS, &c.

1779.	March	.	Mr. Latrobe commenced the first water-works by steam-power.
1812.	August	1.	Commenced the steam-power works at Fair Mount.

1815.	Sept.	7.	Supplied the City from the steam-power works at Fair Mount.
1819.	April	8.	Councils agreed to build the water-power works at Fair Mount.
"	April	19.	Commenced building the Dam at Fair Mount Works.
1821.	April	28.	Laid the Corner Stone of Mill Buildings at Fair Mount.
"	June	25.	Put in the last Crib of the Dam at Fair Mount.
"	July	23.	The water flowed over the Dam at Fair Mount
1822.	Feb.	21.	The great ice freshet, which raised 8 feet 11 inches above the Combing of the Dam at fair Mount.
"	July	1.	Began to supply the City with water from water-wheel and Pump No. 1.
"	Sept.	14.	Began to supply the City with water from water-wheel and Pump No. 2.
"	Oct.	25.	Stopped the Steam works at Fair Mount.
"	Dec.	24.	Started Wheel and Pump No. 3.
1827.	Nov.	10.	Started Wheel and Pump No. 4.
1832.			Started Wheel and Pump No. 5.

The Dam at Fair Mount is 6 feet 6 inches above high tide in Schuylkill.

The Mill buildings are 238 feet front—by 56 feet deep.

The water is raised from the Dam into the Reservoir, 96 feet perpendicular height.

Pump No. 1, raises per 24 hours, into Reservoir, when not impeded by tides,	1,313,280 gallons.
Pump No. 2 and 3 ditto—ditto—each 1,346,400—together, - - - - - - -	2,692,800 "
" Pump No. 4, - - - - - - - - - - -	1,615,680 "
	5,621,760 gallons.
" From which deduct one fourth for impediments by the tides and freshets, -	1,405,440
Leaves the four pumps competent to supply for 24 hours, - - - - - - - -	4,216,320 gallons.

" The average quantity of water required to supply the city and districts for 24 hours, during the year 1831 was about 2,000,000 gallons. In the Summer months, when the streets were washed by means of the fire plugs, upwards of 3,000,000 gallons were consumed daily."

There are two mains leading from the reservoirs to the city of 20 inches diameter and at the time the above report was made, January, 1832, there had been laid within the city nearly 44 miles of cast iron pipes. The following extract from the report shows how prosperous the establishment is. The whole cost of pumping is from 3 to 4 dollars a day.

"From all which it must be apparent, that, in case the water revenue for 1832 shall be equal to that of 1831, of which there can be no doubt, there will be a balance in favour of the works, for the year 1832, of $35,905 05, equal, it is hoped, to all the needful expenditure for 1833; and thus the whole revenue of 1833 may be applied to the extinguishment of debt and the same process be thereafter continued." What were the flourishing prospects of this admirable scheme of water works in 1831, may be learned from the following table combined from those annexed to the report, showing the water revenue for 1831 arising in the City, The District of Spring Garden, The District of Southwalk, and The District of the Northern Liberties. The rate of payment, by the year, is also put down.

An account of the Dwellings, Manufactories, and Institutions supplied with the Schuylkill water, in the City, the Districts of Spring Garden, Southwalk, and the Northern Liberties, for the year ending December 31, 1831.

CITY OF PHILADELPHIA

34	Horses,	at $1 00	$34 00
65	Wash Pavements, &c.	2 00	130 00
102	Tenements, &c.	2 50	255 00
992	Baths,	3 00	2,976 00
3	Taverns,	3 75	11 25
1	Tavern, &c.	13 00	13 00
25	Baths,	4 50	112 50
5959	Dwellings, &c.	5 00	29,795 00
6	Stables, &c.	4 00	24 00
9	Dwellings, &c.	6 00	54 00
2	do.	6 50	13 00
296	do. and in courts,	7 50	2,220 00
91	Hatteries, &c.	8 00	728 00
82	Printing Offices, &c.	8 00	656 00
14	Dwellings, &c.	9 00	126 00
120	Dyers, &c.	10 00	1,200 00
2	Dwellings, &c.	11 25	22 50
14	Soap Boilers,	12 00	168 00
8	Dwellings, &c.	12 50	100 00
1	Dwelling,	13 00	13 00

50 Distilleries, &c. - - - - - -	$15 00	$750 00
7 Hatteries, &c. - - - - - - -	16 00	112 00
1 Court, &c. - - - - - - -	18 00	18 00
1 Stable, &c, - - - - - - -	17 00	17 00
1 Court, &c. - - - - - - -	17 50	17 53
29 Taverns, Courts, &c. - - - - -	20 00	580 00
2 Taverns, &c. - - - - - -	18 00	36 00
1 Court, &c. - - - - - - -	22 50	22 50
17 Sugar Houses, &c. - - - - -	25 00	425 00
1 Steam Engine, - - - - - -	27 50	27 50
1 Tavern, &c. - - - - - - -	29 50	29 50
12 Stables, &c. - - - - - - -	30 00	360 00
2 Courts, &c. - - - - - - -	33 00	66 00
2 Mansion Houses, - - - - - -	34 00	68 00
4 Morocco Factories, - - - - -	35 00	140 00
1 Steam Engine, - - - - - -	36 00	36 00
8 Baths, &c. - - - - - - -	40 00	320 00
1 Marble Yard, &c. - - - - - -	11 00	11 00
3 Hospitals, &c. - - - - - -	50 00	150 00
2 Courts, &c. - - - - - - -	73 50	73 50
1 Brewery, &c. - - - - - - -	44 00	44 00
2 Courts, &c. - - - - - - -	45 00	90 00
3 Stables, &c. - - - - - - -	50 00	150 00
2 Manufactories. - - - - - -	75 00	150 00
2 Breweries, - - - - - - -	75 00	150 00
1 Deaf and Dumb Asylum, - - -	60 00	60 00
1 Bath, - - - - - - - -	80 00	80 00
1 Manufactory, - - - - - -	112 50	112 50
1 Distillery, - - - - - - -	100 00	100 00
1 Almshouse, - - - - - - -	100 00	100 00
1 Sugar House, - - - - - -	335 00	335 00
1 Bath House, - - - - - - -	400 00	400 00
City, - - - - - - - - -		$43,682 25

SPRING GARDEN.

4 Horses, - - - - - - -	at $1 50	6 00
1 do. &c. - - - - - - -	3 00	3 00
21 Tenements, - - - - - -	3 75	78 75
58 Baths, - - - - - - -	4 50	261 00
1 Porter Cellar, - - - - - -	5 25	5 25
21 Dwellings, - - - - - - -	6 00	126 00
676 Dwellings, &c. - - - - - -	7 50	5,070 00
1 Slaughter House, - - - - - -	10 50	10 50
4 Dwellings, &c. - - - - - -	11 25	45 00
5 do. &c. - - - - - -	12 00	60 00
4 Factories, &c. - - - - - -	15 00	60 00
2 Taverns, &c. - - - - - -	22 50	45 00
1 Dwelling, &c. - - - - - -	24 00	24 00
2 Factories, &c. - - - - - -	30 00	60 00
1 Court, &c. - - - - - - -	48 50	48 50
2 Courts, &c. - - - - - - -	37 50	75 00
1 Steam Mill, - - - - - - -	40 00	40 00
1 Tannery, - - - - - - -	57 00	57 00
1 Dwelling, &c. - - - - - -	75 00	75 00
1 Steam Mill, - - - - - - -	30 75	30 75
Spring Garden, - -		$6,180 75

DISTRICT OF SOUTHWALK.

1	Horse,	at $1 50	$1 50
3	Bake Houses, &c.	3 00	9 00
49	Taverns and Licensed Houses,	3 75	150 00
16	Baths,	4 50	72 00
1	Commissioners Hall,	5 00	5 00
12	Dwellings with Cisterns,	6 00	72 00
747	Dwellings,	7 50	5,602 50
1	Dwelling, &c.	9 00	9 00
1	School House, &c,	10 00	10 20
13	Dwellings, &c.	11 25	146 25
3	Hatteries, &c.	12 00	36 00
1	Dwelling, Tavern, &c.	12 75	12 75
8	Hatteries, &c.	15 00	120 00
1	Soap Factory,	18 00	18 00
1	Steam Engine,	20 00	20 00
3	Sugar Refineries,	22 50	67 50
1	Livery Stable,	25 00	25 00
1	Distillery,	27 00	27 00
1	Court, &c.	30 00	30 00
1	Court,	37 50	37 50
1	Brewery,	45 00	45 00
1	Brewery,	60 00	60 00
1	Navy Yard,	75 00	75 00
	Southwalk,		$6,651 00

NORTHERN LIBERTIES.

7	Horses,	at $1 50	$10 50
14	Wash Pavements, &c.	3 00	42 00
68	Tenements, &c.	3 75	255 00
83	Baths,	4 50	373 50
2	Stands for Horses, &c.	5 00	10 00
72	Dwellings, &c.	6 00	432 00
1360	Dwellings, &c.	7 50	10,200 00
1	Stable,	8 00	8 00
5	Dwellings, &c.	9 00	45 00
5	Factories, &c.	10 00	50 00
28	Dwellings, &c.	11 25	315 00
20	Curriers, Hatters, &c.	12 00	240 00
31	Curriers, Morocco Factories,	15 00	465 00
1	Court,	18 00	18 00
6	Taverns, with Stables,	18 75	112 50
1	Brewery, &c.	19 50	19 50
2	Soap Factories, &c.	20 00	40 00
2	Taverns, with Stables,	21 00	42 00
15	Taverns, with Stables,	22 50	337 50
5	Morocco Factories, &c.	25 00	125 00
9	Soap Factories,	30 00	270 00
1	Brewery,	33 00	33 00
6	Stables with Taverns,	33 75	202 50
1	Morocco Factory,	37 50	37 50
2	Tanneries,	52 50	105 00
1	Brewery,	75 00	75 00
1	Dwelling, &c.	12 75	12 75
1	Stable,	13 50	13 50

Northern Liberties,	$13,889 75
Southwalk,	6,651 00
Spring Garden,	6,180 75
City,	43,692 25
	$70,403 75

Much interesting information is derived from the above tables. They exhibit the rate at which the Schuylkill water is annually furnished at different houses and establishments, and for a great variety of purposes. The luxury of baths is extensively enjoyed, and there can be no doubt that the cleanliness, comfort, and health of the City, are vastly promoted by this and other copious indulgence in the use of the pure river-water. There were, in 1831, 1,184 baths, yielding a revenue of $4,595. Among them there is one bathing establishment, Swaim's, I presume, that pays $400 a year; 8 others paying $40; one at $80; 25 others in the City $4,50; the 992 others in the City pay $3 each; all the rest are in the districts, paying $4,50 each. The mean of the whole is $3,88 for each.

CINCINNATI.

This town, situated on the right bank of the Ohio River, is in a lime stone country and the water from wells is of course too much affected with the usual lime stone qualities, and for several years the inhabitants have enjoyed a supply of good water from the river. To obtain correct information, I addressed a letter to William Green, Esq., one of the most active and intelligent gentlemen by whose exertions these water works were established. He has promply, in a very kind and efficient manner, communicated answers to my inquiries, by sending a full statement drawn up by Mr. S. H. Davis, the Superintendent of the works from the origin, together with a short note by himself. I cannot avoid giving their account, instead of attempting to make one so good of my own.

" To William Greene, Esq.

" I have embraced in the following communication all the information which I have thought it important to know in the construction of a new establishment of the kind contemplated by the City of Boston. The Cincinnati water works were constructed in 1820. The water was taken from the Ohio river by the common forcing pump worked by horse power, and was placed upon the bank of the river sufficiently near low-water mark to be within the usual atmospheric pressure, and thrown from that point to the reservoir 160 feet above low water mark, from which it was conveyed to the City in wooden pipes. The City at that time afforded no inducement for a larger supply of water than could be brought through wooden pipes of 3½ inches in diameter, consequently the works at the river were only calculated to supply a pipe of that size. A short time, however, was necessary to prove the necessity of an increase, and a change from horse power to *steam*. The unexpected increase of the City and the consumption of water, kept it in advance of the supply and from that time they have been constantly increased and enlarged from year to year. The works now consist of 2 Engines, one propelling a double force pump of 10 inches in diameter and 4 feet stroke, throwing into the reservoir about 1,000 gallons a minute, the other propelling a pump of 20 inches in diameter 8 feet stroke and discharging about 1,200 gallons per minute. The reservoirs are built of common limestone; the walls are from 3 to 6 feet thick and grouted. The water is conveyed immediately to the City without being permitted to stand or filter. Iron pipes of 8 inches diameter convey it through the heart of the City from which it branches in wooden pipes of from 1½ to 3½ inches diameter, from which it is conveyed into private dwellings in leaden pipes at the expense of the inhabitants who pay from 8 to 12 dollars per annum, according to the purposes for which it is used. Each family, of course, use any quantity they choose, their hydrants communicating freely with the main pipes. The iron pipes are made in lengths of 9 feet each and connected together by the spigot and faucet joint run with lead, which occupies a space round the pipe of ⅜ or ½ an inch in thickness. Experience has proved here as well as elsewhere, that iron pipes should be used in preference to any others and that it is certain economy to lay down such a pipe in the first instance, as will give an ample supply for any reasonable increase in the town or city about to be supplied. The error has never been committed of creating *too large* a supply, but instances of the reverse are of almost daily occurrence. The foregoing comprehends all that occurs to me now as necessary for the letter in my hands."

"Respectfully yours,

SAMUEL H. DAVIES."

"*Cincinnati, Aug.* 2, 1834."

"N. B. 100 gallons per day will not be found to be too large an estimate for the use of each family.

S. H. D."

Cincinnati, Aug. 2, 1834.

" Dear Sir,

I have lost no time in procuring the foregoing as a reply to your favour of 16th ult. I know of nothing that I can add, except that payments for water are always in *advance* and never for less than *one* year, though we always pay back any unexpired fraction of a year and stop off the supply upon any particular application.

" The gentleman from whom I procured the foregoing has been connected with our establishment from its very commencement. He has great enterprize, industry and integrity, and if, with his present practical experience, he had our works to rebuild he would save us tens of thousands of useless expenditure. In my judgment he is just the man to act as your principal assistant in the work you propose, and I should think a salary of 1,500 or 2,000 per annum might be well afforded for such a man as connected with the permanent economy of such an establishment."

" Very respectfully,

" WILLIAM GREENE."

RICHMOND, VIRGINIA.

I am indebted to the Hon. B. W. Leigh of Richmond, for sending me a copy of the Engineer's report of the water-works made by the Watering Committee on the 11th of January 1832, and read before the Common Council of the City on the 12th. Mr. Albert Stein was the Engineer who planned and superintended the Execution of the works for supplying the City of Richmond with water from the James River, and on the termination of the works he made a long and detailed report of all parts, from which the following abstract is made.

An Engine House 56 feet long and 58 feet wide is erected of Stone on the bank of the river with the upper story of brick and only 32 wide and 10 feet high, which is intended for the keeper or guardian, and the lower part for two wheel pits and two pumps, which appear by the report to have been constructed and applied in a similar manner to the works at Philadelphia. Only one wheel and a double horizontal forcing pump connected with it was erected at that time.

The water wheel is of iron with the exception of the buckets and soling, 18 feet in diameter to the points of the buckets, 10 feet wide between the shroudings and 14 inches depth of shrouding. The cast iron shaft of the water-wheel is 10 inches in diameter in the journals and 16 feet 6 inches long. The crank wheel to which the connecting rod is attached is 7 feet in diameter, with a rim of 3½ inches thick and 5 inches wide, and hooped with wrought iron around the socket. The head and fall of the water is 10 feet. The barrel of the forcing pump is 9 inches in diameter, the stroke 6 feet in length and the pump intended to make ten strokes per minute, or raise in 24 hours 400,000 gallons into the Reservoir 160 feet above the pump and when at work the pressure on the piston is supposed to be 6,000 pounds.

The cast iron main from the pumps to the reservoir, is 2,400 feet long, 8 inches diameter and for 450 feet from the pump is ¾ of an inch thick, and for the remaining distance of 1,950 feet to the reservoir is only 9-16 of an inch in thickness. The reservoir is 194 feet long 104 feet wide and 10 feet 8 inches deep and contains upwards of a million gallons. It is divided into four apartments, two of which serve for filtering. The top of the partition wall is 12 feet above the highest ground in the City and 182 feet above the Market bridge in E street, the lowest point in the line of pipes. The filter is 22 feet 6 inches long and 16 feet wide and the process of filtering is effected by the water ascending upwards from the bottom, and the sediment is washed away by discharging water downwards from the top. This reversing the course of water through the filter appears to be like the plan adopted by Mr. Thom at Greenock.

The length, diameter, thickness and cost per foot, of pipe laid in Richmond are stated below. The pipes and other castings were delivered in Richmond by Messrs. Samuel and Thomas Richards of Philadelphia, at the prices stated.

Diameter.	*Thickness.*	*Length laid.*	*Cost per foot.*
10 inches,	9-16 inches,	"	$1,38
8 "	3-4 "	"	1,25
8 "	9-16 "	"	1,20
6 "	7-16 "	9,816 feet,	70
4 "	1-2 "	6,040 "	50
4 "	7-16 "		45
3 "	7-16 "	7,013 "	37
3 "	3-8 "		34

The stop cocks and fire plugs were made by Messrs Mingle and Son in Philadelphia, at the following prices.

10 inch stop cock with brass faces, cast iron excepted,					$70 00
8	"	"	"	"	56 00
6	"	"	"	"	43 50
4	"	"	"	"	33 00
3	"	"	"	"	28 00
A fire plug, including eye bolts				"	16 00

The whole amount stated by Mr. Stein as paid by the Chamberlain of the City for the works, is $76,860 83.

The Clerk of the City Council has added to the copy of Mr. Stein's report from which the foregoing statement was drawn, the following note.

" Mr. Stein has omitted to state in his report, that the pump and water wheel were furnished by the West Point Foundry Association, (William Kemble Agent) New York.

" Since the completion of Mr. Stein's contract, another pump and wheel have been erected, of the same size of the first, and to work *alternately* with that, and in case of accidents, &c. They were also procured from the West Point F. Association, upon not quite so good terms as the first, but with some improvements in the construction of the wheel.

" Another Reservoir of equal size with the first, with a filter between the two, is not completed yet. It has been constructed with the view of cleaning the water, which at times has been found too muddy for use. The first filter does not seem to have had much effect in purifying the water. The second differs from it, in filtering *downwards* instead of by *ascending*, and it is expected when in operation, to render the water fit for use at all times, with the aid of the *settlement* in the New-Reservoir.

" These improvements with the extension of pipes into other streets, and the compensation of the Engineer (not included in the report) have made the cost of the works to this time about $100,000.

" W. P. S. *Clerk C. C.*"

SUPPLY OF WATER FOR BOSTON.

The first inquiry is, what will be " a copious and steady supply of pure and soft water" for the town of Boston ? From the foregoing sketch of several plans for furnishing towns, no practical scale can be framed to graduate the quantity to each inhabitant. Mr Treadwell fixed the quantity at 1,600,000 gallons daily, in his plan for furnishing water from Charles River or Spot Pond, and the population was a little over

61,000 in 1830. In 1840 the census will probably be 80,000, and the water he proposed introducing would then be 20 gallons for each, and as population increases, the ratio diminishes. But much would be lost by waste and leakage, and the supply would be limited to the discharge of Spot Pond, if taken from that, or by the machinery if brought from Charles River at Watertown. In addition to what is wanted for the inhabitants a vast quantity would be taken by the shipping, and could be profitably supplied by the town.

To make any prudent estimate of water required from distant sources, it became necessary to ascertain pretty correctly what was the character of the town water, and what the nature of the geological structure of the Peninsula for ordinary wells. By my inquiries I could obtain no correct, definite information sufficient to establish a proper scale of works for the object the City Council had in view. I therefore employed Mr Eben. A. Lester to make a careful investigation as to the number of wells in town; to collect all facts from the owners or occupants as to the character, quality, and uses of the water taken from them in every street, and to make a table shewing the number, with the peculiar kind of water they furnished for domestic use. The result of his researches is very curious; and his report is full, with a table shewing in detail all the wells distributed into seven different classes.

The following abstract is given from this Table.

Whole number of Wells, - - - -		2,767
Water drinkable in, - - - - - -	2,085	
" bad, - - - - - - -	682—	2,767
" hard, not used for washing, - -	2,760	
" soft, occasionally used for washing,	7—	2,767
" fail, - - - - - - - -	427	
" injured by vaults, drains, or are nuisances, - - - - -	62	
" brackish, bad, tolerable or turbid, but drank, - - - -	134—	630
Bored, or Artesian Wells included in the above, - - - - - -	33	
Wells at Distilleries, - - - - -	18—	51

Within a few years it has become common in Boston and the vicinity to bore for water aud to make what are called Artesian Wells. But no certain and valuable result has grown out of these endeavors. I cannot find that any geological science has been acquired by any one to guide or to check those fruitless attempts ; and great sums of money are idly expended every year upon mere projects founded on guesswork. In my previous remarks relative to Artesian Wells, a few instances were given where this mode of obtaining water was valuable ; such as at Knightsbridge and Hammersmith in the neighborhood of London ; in Artois and the vicinity of St. Denis, in France ; and Norfolk in Virginia. Many other places may also be named ; but the Geological formation of the Peninsula of Boston seems to afford no certain resource of this kind. There are 33 bored Wells, as given by Mr. Lester, only two of which are stated as furnishing soft water.

All the dug or Artesian Wells of Boston, are in strata of different materials in very irregular position, so that whatever may be the success in making one well, no certain result can be predicated upon another trial at a short distance from the first. The wells in town are polluted by the dirty water at the surface being absorbed, settling and mingling with the veins below ; or are adulterated by mixture with little streams of sea water. That the latter case frequently occurs is very natural, as can be illustrated by the following facts.

In excavating in hard compact gravel mixed with some clay, for the foundation of the Dry Dock in Charlestown Navy Yard, at the depth of about 40 feet, they came to a small spring of fresh water on the S. W. side next the ship house, a few feet outside the exterior line of Masonry. This became valuable and convenient to use in the mortar. But it was necessary also to separate it from another spring of salt water which arose within a few feet of it. This was done by sinking a hogshead. and puddling it all round with clay to preserve it pure. In this way fresh water was furnished from this little spring for making mortar throughout the whole work and no other fresh water was used. Had any one attempted to dig a well from the surface on this spot he might have hit the salt instead of the fresh source, or both, and his well be good for nothing. So on the opposite side of excavation, near the head of the Dock, where the hard gravel stood perpendicular for 30 feet, two similar springs issued from the side 20 feet from the surface, within a few feet of each other, one of which was of beautiful pure water, frequently drank by workmen and the other was salt as sea water. The same geological phenomena doubtless exist in most parts of Boston where the same kinds of strata are found in well digging.

From these circumstances it seems advisable not to confine the supply to any limited wants founded on what the town actually affords, but to provide for a supply for all purposes whatever within the town, and to render it copious and convenient to every section of the City, and sufficient for fountains in the squares and other public places. With this view I have examined the subject and think I can satisfy the committee, that two or three million of gallons more or less, will make but little addition to the expense, when compared with the immense advantages. I shall therefore proceed to the investigation of the means of supplying or of bringing within the control of the town 5 million gallons daily.

The water brought in from Jamaica Pond by the Aqueduct Corporation is found to be excellent, and together with a vast deal collected in rain water cistern is wholly used for washing. During the last year the Directors requested me to examine their whole scheme of water works, and report upon the best method of extending their establishment, and making it more generally useful to the public. Engagements with government prevented me from attending to it then, but last spring I performed these services in part, and as the interest of this company may become the subject of inquiry by your committee, I take the liberty of inserting, in the Appendix (A), a copy of my report made in May last. This establishment will not interfere with any plan the town may have in view, as the corporation will be perfectly ready to surrender their franchise to the City upon equitable and fair terms, to be determined by disinterested and intelligent persons, if the corporation and the City authorities cannot adjust it themselves.

There are many Ponds within the distance of about twenty miles from which a supply of pure water may be had by its natural flow to ground, within four or five miles of Boston, sufficiently elevated without the intervention of machinery, to pass through pipes to the highest points of the City and even to flow upon the floor of the State House. Some of these ponds, which have been examined. are put down in the following table. Most of them have been analysed by Dr. C. T. Jackson, and found to be sufficiently pure. They are all high enough, but they are not all equally adequate for a steady and copious supply. In the table, the letters are marks of reference, used by Dr. Jackson in his clear and valuable analysis, as given by his report in the Appendix (B.) Column 1, is the name of the Pond; 2, the town where situated; 3, the areas in acres, quarters, and rods; 4, the height of surface above marsh; and 5th column, the distance from Boston.

LIST OF PONDS, &c.

	Name of Pond.	Town.	Area A. Q. R.	Ft. above Marsh.	Distance, mls. qrs. rds.
A	1. Spot Pond,	Stoneham,	260 " "	143 58	
B	2. Waltham Pond,	Waltham,	52 0 51	192 67	11 3 55
C	3. Sandy Pond,	Lincoln,	152 1 24	222 95	16 3 26
D	4. Baptist Pond,	Newton,	33 2 24	137 46	9 3 40
E	5. Punkapog Pond,	Canton,	217	147 77	15 0 41
F	6. Charles River,	Watertown,			
G	7. Massapog Pond,	Sharon,			
H	8. Long Pond,	Natick,	600 2 24	127 91	24 3 08
I	9. Farm Pond,	Framingham,	193	149 37	26 2 60
	10. Shakum Pond,	"	89 2	155 01	27 0 20
	11. Learnard's Pond,	"	36	158 32	27 1 70
	12. Dug Pond,	Natick,	30 ?	133 66	24 0 63
	13. Morses Pond,	Needham.	20 ?	112 40	20 0 70
	14. Bullards Pond,	"	35 ?	104 45	19 0 7

1. *Spot Pond*, in Stoneham, was contemplated by Mr. Treadwell, in his report of November 4, 1825, as a source for supplying the City, to be brought in cast-iron pipes. But it is very doubtful whether it would be sufficient for furnishing 1,600,000 gallons daily, which he recommended to be brought into town. Besides, the mode of bringing it across the beds of two salt-water rivers, the Mystic and Charles, by iron pipes, appears very objectionable, and the intermediate country is too low and irregular for an aqueduct. The area is 260 acres, and it is 143.58 feet above the marsh in Medford. The result of Dr. Jackson's examination is favorable to the water as marked A. No good opportunity has occurred this season to measure the discharge. All the water flowing from it escapes by leaking through the dam and gateway, exeept the gate, which is occasionally drawn for the mills below, during the present wet summer. It was shut on the 7th September; and on the 10th, by measuring the velocity of the current in the ditch, some way below the dam, the discharge was found to be 1.67 cubic feet a second by Dubuat's formula, and the 1,600,000 gallons, proposed by Mr. Treadwell, is =2.41 feet a second, which is to this calculation nearly as 3 to 2.

2. ***Waltham Pond***, in the north part of Waltham, near

Sherman's Hill, on Hale's map, is 192.67 feet above the marsh level in Watertown, and has an area of 52 acres. From the analysis made by Dr. Jackson, and from its character in the neighborhood, it is not sufficiently pure. This is marked B in the table.

3. *Sandy Pond*, near the meeting-house in Lincoln, is a beautiful lake of 152 acres, and 222.65 feet above the marsh. The whole shore is formed of sand and gravel. It is furnished by springs, but its discharge does not appear adequate to the supply, though it has not been guaged. It appears from Dr. Jackson's trial to be the most pure, from its specific gravity being equal to pure water. It is C in the list. The whole intermediate country to high land in Roxbury or Dorchester is mostly too low and very unfavorable for an aqueduct, and the distance too great for pipes.

4. *Baptist Pond* in Newton near Dr. Homer's Church, is only 33 acres and an half and 137.46 feet above marsh level. It is a beautiful sheet of water in a gravelly bason, fed by springs, and has a small outlet, but is too small for the occasion, unless like many others, it be united as a feeder to some other source. Its place is D in the table.

5. *Punkapog Pond* in Canton has an area of 217 acres and 147.77 feet above marsh level, or high water mark at the mouth of Neponset River. From the appearance of the pond and of the copious discharge from it, it was hoped that this was a practicable and abundant source, and the analysis of Dr. Jackson marked E, shows it to be sufficiently pure. But on trying the levels, in two or three directions, the ground was too low for an aqueduct. Finding these circumstances unfavourable, I turned my attention next to sources in the west and examined the Ponds in Natick and Framingham. But attempts were subsequently made to find the amount and to guage the discharge from Punkapog. The U. S. Engineers on their surveys for the Weymouth Canal, in 1830, had the outlet guaged by allowing the water to flow through a weir or notch 24 inches wide and it was found to be, as I am informed, 10 inches deep, which gives by a rule in Robison's Mechanical Philosophy, II Vol. page 515, 5.10 cubic feet a second. But five million gallons daily would require 7.7 cubic feet. This measurement was during a dry summer, and much water escaped by leakage at the weir. On the 11th of September, I attempted to guage the water flowing through two gateways at the mills about a quarter of a mile below the pond. At the

mill-gate it was 15 cubic feet a second, and at the guard-gate, at the head of the mill-pond, it was over 12 feet. But the measures attainable at these points could not be considered accurate, though sufficient to show the supply is ample at this season.

6. *Charles River* water. This specimen, F, was taken by the falls in Watertown, at the head of tide-water. This river-water was formerly, and still is by some, used in the manufacture of paper of all kinds, but was soon found to be unfit for the finer kind on account of its having a dark tinge usual in boggy or ditch water. Such was the effect of this discoloration several years ago, when paper was made at the mills of Bemis & Eddy, at the second dam above Watertown bridge, that they were at the expense of conveying pure water to the manufactory from a distant spring for making the best sort of paper. Some families, who still use the river-water for washing, do all the rinsing with that of a spring. The Waltham factories, next above on the same stream, carry on an extensive bleaching operation, in connexion with the manufacture of cotton cloth, and sometimes employ the river-water, but it often gives a shade of reddish tint to the goods, and spring-water is used for rinsing. Complaints are occasionally made on this account by customers in Boston for whom they bleach, and the bleaching is performed wholly with spring-water. The river-water at times is much clearer than at others, and the discoloration is probably much increased of late years, in consequence of the extensive but shallow flowage over meadows and swamp land, caused by the upper dam of the Waltham factories having been raised. These facts I have from Caleb Eddy, Esq., Seth Bemis, Esq. and from Dr. Hobbs, agent of Waltham factories, whose statement in writing is in the Appendix C, with a second letter from Dr. Jackson.

The water of Concord River, from Sudbury to the Middlesex Canal at Billerica mills, has the same defect as to its discolored state, together with the additional objection of its possessing some poisonous quality. I remember when the locks, &c. of the Middlesex Canal were built 30 or 40 years ago, the workmen obliged to labor in the water, complained that it made their hands and feet sore, and if a little scratch occurred to their flesh, or the skin was torn or bruised away, the water would cause it to fester into a serious wound, and it was often necessary to suspend working in it that the sore might heal. This character of the water was confirmed to me a few days ago by Mr. Wilson, a master Carpenter, who has been employed 20 years in the direction of the Canal works there, whose expression was "if a man gets a little piece of skin knocked off his hand while working in it, the water would fester it up so that I don't know but it would eat his hand up in time; but working in the Merrimack river would wash it well again."

This natural defect of streams flowing through extensive boggy soil and lying as the water does in winter and spring, and often in summer, upon immense fields of morass lands bordering on the Charles and Concord, should induce great caution in taking their waters for the supply of towns. On the other hand, rivers springing from pure lakes and mountain brooks, and flowing throughout in rocky, gravelly and sandy beds like the Merrimack, must always be free from pernicious vegetable solution.

7. This specimen of water was taken from *Massapog Pond* in Sharon and is marked G. Analysis has given it a good character; but there are the same objections to bringing it in an aqueduct which exist to that of Punkapog. Its elevation above the tide has not been ascertained, nor has it been surveyed.

8. *Long Pond* is situated in Framingham and Natick but about six sevenths of it are in the latter town. From a calculation on the plan made on the late surveys of the Commonwealth, the area is 600 acres and its surface 127.91 feet above marsh level. The first specimen of water tested by Dr. Jackson marked H, was taken from the south end of the pond and was not so favourable a sample as that subsequently obtained at the outlet, and of which his analysis is more satisfactory as he mentions in a note. At the outlet which falls into the Concord River is a Cotton factory and at the mill race just above the mill was a convenient place to guage the discharge while the machinery was in motion, which was done on the 16th August last. The race was 12 feet wide with parallel, perpendicular side walls for the distance of 30 or 40 feet. Two straight timbers were found lying across the top of the race at right angles with it and 18½ feet apart. The bottom was very nearly level and the mean area of the two sections of the stream, one under each cross timber, was 32.08 feet and sufficiently correct for the whole stream. It was next required to ascertain the velocity in inches of the top surface along the middle of the current, which was found to be, on the mean of

6 trials, equal 18½ feet in 18 seconds. To obtain the mean velocity of the whole section, Dubuat gives the following formula : $V=(\sqrt{A}-1)^2$ and $\frac{A+V}{2}=C$, where A=top velocity in inches per second; V=bottom velocity, and C=mean velocity ; both also in inches. By this formula the mean velocity reduced to feet per second, multiplied by the mean area of section in square feet, gives the discharge=24,89 cubic feet a second. Prony's more simple formula viz : A × 0,8 =26,35 cubic feet for the discharge. Taking 25 for the mean of the two formulas, the result is 2,160,000 cubic feet or 16,156,800 gallons in 24 hours. This Pond is evidently sufficient for a supply, but it will become important on account of its relative level compared with the next two, and the greater expense of effecting a discharge from it, to know if they and other sources will not also be fully adequate ; for if they are not, I propose relying on this.

9. *Farm Pond* in Framingham, marked I, has its outlet into Sudbury River, which unites with the Concord in the same town and is the last submitted to analysis. Its area is 196 acres and 149,37 feet above the marsh. It is 21,46 feet higher than Long Pond and about two and a half miles to the west of it. The outlet passes first through meadows about 40 rods ; then through hard land and joins the Sudbury River in meadow land, the whole fall from the pond to the river being 2 feet 11 inches in a distance of 134 rods. In the ditch leading through the first meadow is a stop gate opened and shut occasionally in dry seasons, for the use of mills situated some distance below at Saxonville Village on Concord River, in Framingham. On this account it became very difficult to guage the stream during the driest part of the last summer. On making a trial on the 15th August, in the same manner as that used the day after at the outlet of Long Pond, it was found to be equal 0.766 cubic feet a second by Dubuat's rule and 0,954 by Prony, the mean of which is 0,86 feet a second =74304 cubic feet or 555794 gallons daily The land on the South side is only two feet above the pond and during winter, spring, or high state of the pond, the water flows over and passes down the meadows to Long Pond, in a direction opposite that of the natural discharge to Sudbury River.

10. *Shakum Pond* in Framingham has the appearance and the character of being a collection of clean, pure water, but has not been analysed. It is half a mile south of Farm Pond and contains 89 acres and is 155,00 feet above Marsh

level, 5.64 feet above Farm and 27.10 above Long Pond. There are two outlets on the south side and it discharges into Long pond. Both outlets were stopped for the farmers to get their hay on the extensive meadow below, when the other guages were taken and no trial could be made as to the discharge. It is wholly fed by springs. It is from Farm Pond with this, together with copious additions from springs every where indicated for several miles, through which an aqueduct must be cut, that a sufficient supply can be expected; but Long Pond is abundant, though the excavation will be deeper. The character of the route from each will be given below. The supply is apparently equal that of Farm Pond.

11. — *Learnard's Pond* is about a quarter of a mile north east of Farm Pond in the same town; containing 39 acres 158.26 feet above marsh, 30.35 above Long, 8.89 above Farm and 3.25 feet above Shakum Pond, but has neither inlet nor outlet and is supplied wholly by springs. It is a clean basin of clear water in a gravelly bed, fluctuating by change of seasons, and perhaps deserving no further notice for our purpose.

12. *Dug Pond*, in Natick, is supposed to contain about 30 acres, but has not been surveyed. It lies a quarter of a mile to the south of, discharges into, and is 5.75 feet above Long Pond. Several years ago, the outlet was deepened by the owners of mills at the discharge of Long Pond, for the purpose of making it a reservoir. The consequence was that the pond was drawn down about 7 feet to it present level, where it has remained for some years, having been found ineffectual as a reservoir. Its shore all round is a steep gravelly bank, eight or ten feet high, and it is furnished wholly by springs. It was through this Pond I first contemplated cutting an aqueduct from Long Pond, but a preferable route has been examined, and the far more favorable direction from Farm Pond, &c., render this line inexpedient.

Morse's and Bullard's Ponds, in Needham, will be noticed on the second route from Long Pond, but as a supply are of little or no consequence.

From a consideration of all the sources I have examined in the vicinity of Boston, as before stated, the most eligible are those of Farm and Shakum Ponds in Framingham, together with incidental ones dependent upon them and Long Pond, in Natick, and the mode of bringing the water to town is by an aqueduct, without the use of pipes, to the nearest point of sufficient height to allow it to flow through cast-iron pipes to the highest land in the City.

For this purpose, I propose establishing a reservoir near the road leading from Roxbury to the Brush Hill Turnpike, by the rocks on the west side of the road north of R G. Amory's house, or some place in that neighborbood. The reservoir to be of such form and dimensions as the nature of the ground and future surveys may justify, and of such height that the surface of the water, when full, shall be 110 feet above marsh level. The aqueduct to be formed in the earth like an open canal, or made of stone and covered, with such form, dimensions, and slope, from the source to the reservoir as to be adequate to conduct five million gallons at least to the reservoir daily, for the use of the City, should it be required, but in which the supply shall be easily restricted to any less quantity.

From the surveys already obtained which are mainly on the most eligible routes, but which must be considered only as trial levels and surveys, the distance from Farm Pond to the proposed reservoir is 23 miles and 3 quarters; that from the south end of Long Pond, through Dug Pond to the same point, is 21 miles 3 quarters; and that from the east side of Long Pond nearly 22 miles. The route thus indicated is common to all the resources, westward from the reservoir or basin, for the distance of 16 miles, but the difference in the lines before given, takes place above that point where they diverge. The position and profile of the surveys and levels will be seen on the plan.

FORMS OF AQUEDUCT.

Four plans for constructing an aqueduct are given. *First*, an open canal or drain, like common navigable canals, but on a small scale. Such is the New River, which has supplied part of London for two centuries, and such is the Ourcq Canal, furnishing Paris with pure water, though upon a much larger scale to answer also for inland navigation. This mode has nothing but economy to recommend it, for unless other objects, than solely furnishing water for domestic use are wanted, in every other respect it is objectionable.

A *second* mode is to build stone walls four or five feet high, instead of leaving the sides of the aqueduct or canal of natural earth. This would tend to protect the canal from filling and choking by the bank's washing in, and lessen the liability of encroachment from the growth of weeds and aquatic plants along the borders. In most cases, more especially where stones are abundant and convenient, it would be much better than the first.

A *third* kind, and in many places preferable to the other two, is a drain with stone walls laid up on each side without mortar or cement, two or three feet apart, three or four feet high, with flat stones to cover the top, and earth laid over the whole, so as effectually to conceal the work from sight, protect it from mischief and frost, and leave the ground free for ordinary use. This resembles the admirable scheme adopted for furnishing a supply of pure spring-water for the City of Edinburg, and which is to be recommended for some miles in this, to secure the acquisition of spring-water that plan affords.

Finally, the *fourth* construction is that furnished by Ancient Roman works, and nearly all, except open canals, used in Europe, which is like the *third* in form, but built in regular masonry, laid in hydraulic cement, or in common mortar, and lined with cement. In this, the bottom should be stone, the top covered with the same, and the whole laid under ground, or where the foundation is too low, the work to be surrounded and covered with an embankment. Before proceeding to a description of the proposed aqueduct and estimate, I will present for the consideration of the Committee a table exhibiting the effective discharges of several canals and aqueducts, founded on the modification of the form, dimensions, and slope of different plans, compared with that of a cylindrical pipe having the same area of cross section with the aqueducts.

In the following table are given seven cases or forms of canals or aqueducts, showing in each the area or cross section, the slope in inches a mile; the velocity of discharge a second; the discharge a second in cubic feet; and same in 24 hours, the measures all in feet: 1st.—An open canal 4 feet wide at bottom, 4 deep, with banks sloping with 1.5 feet base to 1 rise, the area being =40 square feet —2d. Similar canal, but 5.13 feet deep, area =60 feet.—3d. An open canal, 5 feet wide and 3 deep, with perpendicular sides of stones, with an area of cross section =15 feet.—4th. Canal of same form, with depth 3.46 feet, and width 6.50 feet, the section 22.50 feet.—5th. A stone Aqueduct, of 8 feet cross section, 2 feet wide and 4 high, covered with stone and earth.—6th. Another of stone, but equilateral, having the same section of 8 feet. 7th. A conduit pipe 3.19 diameter, giving a cross section of 8 feet.

FORMS OF CANAL AND AQUEDUCT.

Kind of Aqueduct.	Area.	Slope per Mile.	V. a sec.	D. a second.	D. C ft. in 24 hours.
1. Open Canal, bottom 4 wide, 4 deep, 16 feet wide at the top and slopes 1.5 base to 1 foot rise.	40	4	1 0409	41,6340	3597177
		6	1,2686	51,9440	4487961
		8	1,5132	60,5280	5229619
		10	1,7061	68,2440	5896281
		12	1,8788	75,1520	6498132
		18	2,3244	92,9760	8033126
2. Open Canal, bot. 4 wide, same slopes, 5.13 deep and top breadth 19.39 feet.	60	4	1,1645	69,8700	6036768
		6	1,4502	87,6120	7516836
		8	1,6904	101,4240	8763033
		10	1,9021	114,1260	9860486
		12	2,0935	125,6100	10852704
		18	2,5875	155,2500	13413600
3. Canal 5 feet wide, 3 feet deep, with perpendicular sides of stone masonry.	15	4	,8053	12,0795	1043668
		6	1,0083	15,1245	1306756
		8	1,1797	17,6955	1528891
		10	1,3309	19,9635	1724846
		12	1,4676	22,0140	1902009
		18	1,8205	27,3075	2359368
4. Canal of same form 3.46 feet deep and 6.50 wide.	22,5	4	,9173	20,6392	1783226
		6	1,1289	25,4002	2194577
		8	1,3191	29,6797	2564326
		10	1,4868	33,4530	2890339
		12	1,6385	36,8662	3185239
		18	2,0299	45,6727	3946121
5. Aqueduct of stone, either with or without cement, 2 feet wide and 4 deep.	8	4	,5085	4,0680	351475
		6	,6597	5,2776	455984
		8	,7770	6,2160	537062
		10	,8813	7,0500	609120
		12	,9764	7,8118	674939
		18	1,2248	9,7984	846581
6. Aqueduct with equilateral sides, same area of cross section, each side being 2 feet 10 inches nearly.	8	4	,5250	4,1600	359424
		6	,6639	5,3112	458887
		8	,7822	6,2576	540656
		10	,8875	7,1000	613440
		12	,9833	7,8664	679656
		18	1,2338	9.8704	852802
7. Cast iron Conduit pipe, same area of cross section as the two last aqueducts, 3.19 feet diameter.	8	4	,5581	4,4648	385758
		6	,7058	5,6464	487848
		8	,8316	6,6528	574801
		10	,9435	7,5480	652147
		12	1,0454	8,3632	722580
		18	1,3117	10,4956	906819

The 1st construction of an aqueduct or canal is the most simple and economical, and will furnish more water than required. The quantity proposed is five million gallons daily, equal to 668,450 cubic feet, or 7.7367 feet a second, while the canal would give 41,634 feet a second, or about six times what is wanted. But it must be considered that an open canal is liable to fill up and be choked, and if reduced below the dimensions given in the table, this circumstance will soon produce serious inconvenience. In common earth, such a canal in 6 feet cutting would cost, at 15 cents the cubic yard, $2288 a mile.

The third, an open canal, 5 feet wide and 3 deep, with the sides formed of stone walls, is much preferable to the other, and the excavation 6 feet deep and 11 wide, at 15 cents the yard, would cost, per mile, - - - - - - $1,180

The side walls, 4 feet high and mean thickness of 2 feet, at $2 a yard, - - - - - - 5,866

$7,746

An open canal, like either of these, will be exposed to the frost, and the ice which will cover them in winter will lessen the discharge about one third in the former, and little more than a quarter in the latter form, with a slope of 4 inches in the mile, when the water beneath the ice has the same depth as noted in the table.

A close stone aqueduct, like the 5th case in the table, is the most proper construction. The 6th is only a change of form; and the 7th being a cylindrical pipe, is added to show the difference of discharge arising from a simple change in form of the same area of cross section, which is 8 square feet in each of the three.

No reduction of dimensions from those above given, can be made in an open canal, even for a less quantity than five millions, and that the Committee may judge how far the stone aqueduct can be reduced for a shorter supply, the following statement furnishes convenient data for comparison:

1,000,000 galls. =	1.5473 cubic	ft. a sec. or	133690 ft	a day.
2,000,000	" 3.0946	"	267380	"
3,000,000	" 4.6420	"	401070	"
4,000,000	" 6.1893	"	534760	"
5,000,000	" 7.7367	"	668450	"

Now in reducing the aqueduct, 5th case, to 6 feet instead of 8 feet cross section, by making the sides 3 feet high, the discharge, at 4 inches slope in the mile, will be only 249588 ft. or 1866918 gallons daily; and if the same reduction be produced in the cross section by making the breadth 1 foot 6 in. keeping the same height of 4 feet, the discharge will be still further reduced more than 90,000 gallons. Hence it will no be expedient to calculate upon an aqueduct on a smaller scale, unless peculiar circumstances of ground, change of direction or slope, which will probably often occur, shall require.

PROPOSED LINE OF AQUEDUCT.

Farm Pond, the highest source in view, is 149,375 feet above marsh and 39.375 above the basin in Roxbury. Its situation is favourable and very remarkable, being only 2 feet 11 inches above Sudbury River on the north, into which it has its natural outlet at a distance of 134 rods. The surface of land above the Pond on the south side, through which it would require cutting, is about 2 feet, though the survey was carried on higher ground, as shown on the profile, to lessen the distance. By digging 5 or 6 feet deep, therefore, for about a mile or mile and a half, the whole of Sudbury River, with all the rain water falling upon its extensive valley, may be here intercepted and conducted through Farm Pond into the Charles, instead of pursuing its natural course to the Concord River.

FIRST SECTION.

This Section for the distance of 3 m. 3 qrs. 10 rods to A, is mostly upon a thin boggy soil on a gravelly bed, so that after passing a mile from the pond, the level comes out to the surface of the ground, and almost any convenient level or slope may be taken for this section. Some rock would probably be found, but the ground has the appearance of being porous gravel and full of springs. The position of this, and other lines and levels, will be seen on the plan and profile which accompany and make part of this report.

An open Canal, like No. 1 in the table, 6 feet deep would cost, at 15 cents the cubic yard, $2288, adding for subsidary work makes it $3000 ; and with stone walls, like case 3d, 5 feet wide and side walls 4 feet high, the excavation 11 feet wide and mean depth 6 feet, at 15 cents a yard would be $1880: the walls of 2 feet mean thickness and 4 feet high at $2 the yard, would cost $6258 ; and the whole $8130 per mile.

SECOND SECTION.

From A to B the second section is 4.0.35. This line falls upon the left Bank of Charles River in South Natick, and passes along the valley of that stream to the point B where it meets the Eastern survey from Long Pond. The profile shews and the ground indicates some irregularities on this section, which careful repetition of the survey would remove, but an open Canal may be effected at a mean depth of 8 feet cutting, at 15 cents the yard, for $3754 per mile and subsidiary work will make it $5,000. With stone walls it would be $10,000.

THIRD SECTION.

This section, extending from B to C—6.1.48, is still along the left bank of Charles River. The section terminates at the commencement of the low gound and meadow separating the main from Dedham Island. Much uneven ground is found in this part of the line, but a better direction may be selected, than the profile affords, on repeating the levels. Some projecting points are rock, but they are all small, and with the low lands requiring embarkment, an open canal may be effected for about $7,000 a mile.

FOURTH SECTION.

The embarkment across the low and meadow land to Deadham Island, for the distance of 0.3.71 to D, constitutes the Fourth Section. The level of Farm Pond is 39.375 feet above the level of the Basin, which is 27.72 feet higher than the Charles at this place. The aqueduct must be somewhat higher than the Basin, to allow for the requisite slope. It is called 30 feet, to which it will be necessary to raise the embankment, making the top breadth 20 feet and base 110 feet. I state the length 1 mile, though this section is little less. This embarkment at 20 cents the cubic yard, would cost $76,266. A covered stone aqueduct should be constructed upon this bank, after it has had time to settle, for which purpose the water must be brought upon it as early as possible by a small open canal. Arched road ways, and a culvert for the stream dividing the main from Dedham Island, will be required, which will probably raise the cost of this section to $100,000.

FIFTH SECTION.

This embraces the cutting on the Island and the aqueduct bridge across the river to the right bank, extending 0.2.51 from D to E. The first part will be excavation of about 20 feet deep for half a mile, which, upon a mean breadth of 20 feet will cost, at 20 cents a yard, $7,822. But all this earth with much more will be required for the embankment in the last mentioned section, and may properly be considered as included in that estimate. The bridge, with two arches of 50 feet span and 20 wide, with an aqueduct laid in cement, will require 1,000 cubic yards at $12=$12,000, and this section would therefore cost $20,000. The point of crossing the River is at the old abutments of a Bridge, now removed, which are a few rods below the present bridge from Spring street to Dedham, and is the most favorable within the distance of some miles, for passing Charles River.

SIXTH SECTION.

From the River, passing along the lowest ground to a ridge near spring street in Roxbury, thence east of Spring street Meeting-house crossing the Dedham Turnpike to the east of the Halfway house, to the Providence Rail road, the distance is 4 miles from E to F, and makes the sixth section. Two difficult passages occur in this section. The first is the deep cutting near the road, east of the Meeting-house, as seen on the profile. This will require an average cutting of 25 feet deep for a mile and mean breadth of 10 feet, which, at 20 cents the yard,=$9,777. Since the soil here indicates gravel with springs, if rock is not met, a stone aqueduct 2 feet wide and 4 feet deep, of dry stone rubble, covered with flat stones, will be preferable to any other work. This will require 4,500 yards at $2=$9,000, amounting to $18,777 the mile.

The second very expensive part of the section is the low ground, for one third of a mile, at the east end next the Rail road. This will require an embankment of thirty-five feet mean height, and at 20 cents a yard=$32,854. The other parts of this section may be made an open canal at about $5,000 a mile. The whole section amounting to $64,964.

SEVENTH SECTION.

This is 1.0.18 from F to G, and embraces a bridge over the Rail Road and two accommodation Brides. On further examination a more practicable line may be found, which, however, must cross the road and the valley through which it passes. This will require an embankment from 45 to 50 feet high and altogether will probably cost $150,000.

It may become a question with the Committee, whether cast iron pipes could not be substituted for the high banking in this section and at Dedham Island in the 4th, for in fact these two places are the only points that offer any embarrassment. I give the following statement for their consideration.

Cast iron pipes 1 inch thick at 5 cents the pound, delivered on the line will, at the diameters given below, with a head of 2 feet for the mile, cost and discharge as follows.

Cast iron pipe 1 inch thick.	Diam.	V.	Dis. per second.	C. ft. 24 hours.	=Gallons.	Cost per mile.
do.	18	1.156	2.042	176428	1310681	$47,050
do.	20	1.218	2 655	229392	1715852	52,224
do.	22	1.280	3.373	291427	2179873	57,198
do.	24	1.335	4.190	362461	2710460	62,172

From these data it appears, that even a pipe 2 feet diameter with a head of 2 feet, will discharge at a mile distance, little more than half what is proposed to bring to it, for the use of the town, and at 4 feet head nearly 4 million gallons. If two pipes of 18 inches diameter, are laid with 2 feet head, they will furnish but 2639362 and cost over $100,000. Under all circumstances the preference in favour of pipes is not great, in relation to cost, and when it is considered, that a permanent aqueduct dispenses with all care and expense of reparation, an aqueduct is to be prefered.

EIGHTH SECTION.

On the profile this section, from F to H, appears to be very uneven and is in fact impracticable, but a line may be chosen very favourable so as to bring the termination in the neighbourhood of the point proposed for the Basin or revervoir at H. It is 2.3.55 long, and the aqueduct terminating here, will leave the remaining distance to the State house 2 miles 3 quarters and 12 rods. It is extremely difficult to estimate its cost, as the land is broken and presents much of the Brescia ledge prevailing in Roxbury. A route may be selected, nearly coinciding with the level of the basin, through the whole section, and avoid the elevation seen on the profile above the Basin level. The survey was carried, part of the way, along the road leading from Roxbury to T. K. Jones', or Grove Hall, more than a mile to the bench on the Rock at H, and the adjacent lands admit of a higher line and even appear favorable, for advancing the aqueduct and reservoir half a mile further towards Boston.

The ground affords many opportunities of forming basins near the end, and perhaps it will be convenient and economical to construct the aqueduct into a long and wide canal as a substitute for a reservoir. A covered stone aqueduct, like that proposed in the 3d. section will cost $8,131 per mile, but the best mode is to build it in cement with the sides and bottom plastered also with cement. This would cost at $10 the yard and 50 cents a square yard for plastering, $35,933 a mile. The character of the soil may not require this construction;

but if it is sand, gravel or other porous and absorbent earth, this work in masonry laid in cement cannot be dispensed with. Taking into view the irregular surface, this section will cost $12,000 per mile.

ESTIMATE.

	M.	Qrs.	Rods.		
First section,	3.	3.	10	- -	$11,344
2d. do.	4.	0.	35	- -	20,547
3d. do.	6.	1.	48	- -	44,944
4th. do.	0.	3.	71	- -	100,000
5th. do.	0.	2.	51	- -	20,000
6th. do.	4.	0.		- -	64,964
7th. do.	1.	0.	18	- -	150,000
8th. do.	2.	3.	55	- -	36,062
	23.	3.	48		$446,861
Add for contingencies,				- -	53,139
					$500,000

From the reservoir to the State house the distance would be 2 miles 3 quarters and 12 rods. The fall from the top of the basin to the floor of the building would be 14 feet, and a pipe 18 inches in diameter would discharge at that level, making some deductions for sinuosities, upwards of 2 million gallons daily; and a similar pipe would discharge upon the top of Washington Square at Fort Hill, about 50 feet below the level of the reservoir, supposed the same distanse, little less than 4 millions. Such a pipe would cost taken at 1 inch thick and 5 cents a pound, $47,050 a mile, and for the whole distance, either to the State house or Washington square $131,150. If therefore we add for digging the trench and laying the pipe, making the cost =$150,000 for the main conduit to the town, which may be relied upon as a very safe calculation, and to this be also added $100,000 more to contingencies in the estimate of the chief line to the Basin, which is an average of contingencies of more than $6,300 a mile over the estimate, the whole expense of bringing a most copious supply into the City will not exceed $750,000. I omit all calculation as to the distribution in town, as every thing in relation to that branch must depend upon the quantity brought to distribute.

The supply from Long Pond by either survey is quite practicable but will be more expensive than the line from Farm Pond. From Long Pond the distance is a few feet more than 6 miles, when the survey falls into the route from Farm Pond at B the end of the second section. One mile would require digging to the average depth of 25 feet and would cost the same as the deep cutting in the 6th section or $18,777. The remaining distance would amount to $7,000 a mile, and the whole to $53,777, being a substitute for the two first sections of 7 miles and 3 quarters estimated at $31,891. The other line from the South end of Long Pond through Dug Pond is more unfavorable. Both lines with the profiles are seen on the plan. Should any doubt exist as to the sufficiency of supply from Farm and Shakum Ponds, with what will come from springs for a distance of several miles, with numerous little brooks, &c. which can be intercepted along the left bank of Charles river, the adoption of Long Pond resource will add between 20 and 30,000 dollars only.

Upon the whole, the proposed line of aqueduct is the best of any I have been able to discover to any competent source within the same distance from Boston, and with the exception of the low ground at Dedham Island and on the east side of Providence Rail road, presents extraordinary facilities for the intended object, which no one could have supposed attainable from the known irregular character of the surrounding country. The surveys have been made by Mr. Perham and Mr. Ellison assisted by other gentlemen in my office, under my directions, but with little of my own personal inspection. I have however reconnoitered the routes, and on a renewal of the levels, more of my personal attention in the field will be required than I have yet been able to bestow. In making up the report I have endeavoured to make the subject familiar to the Committee and the Inhabitants so deeply interested in the object.

With great respect your obedient servant,

L. BALDWIN, *Engineer.*

To Gen. Theodore Lyman, Jr.
Mayor, aud Chairman of the Committee.
Oct. 1, 1834.

NOTES.

(1.) — *De l'Art du Fontenier Sondeur et des Puits Artésiens*, ou Mémoire sur les différentes espèces de Terrains dans lesquels on doit rechercher des eaux souterraines, et sur les moyens qu'il faut employer pour ramener une partie de ces eaux á la surface du sol, á l'aide de la Sonde du Mineur ou du Fontenier. — Par F. Garnier, Ingénieur au corps royal des mines, ancien élève de l'Ecole polytechnique, 1822.

This very valuable work in 4to. with 19 plates, was the result of a premium of 3000 francs offered in 1818 by the Society for the encouragement of National Industry in France, awarded by the Society in 1821 to the author Mr. *Garnier*. The premium was offered in the following terms. "For the best manual, or practical and elementary instructions upon the art of piercing or boring Artesian wells with the miner's or fountaineer's auger, from 25 metres (82 feet) to 100 metres (328 feet) depth and deeper if possible."

(2.) — *Annales des Ponts et Chaussées*, Vol. VI page 313. See a very interesting extract from a report upon Artesian wells employed for the discharge of foul and infected water, and for the purifying of manufactories, made by a commission of the Council of Health attached to the Prefecture of Police, consisting of Messrs. Girard and Parent-Duchaletet.

(3.) — An account of the mode of draining land according to the system practiced by Mr. Joseph Elkington. Drawn up for the consideration of the Board of Agriculture — By John Johnstone, Land Surveyor, London, 1801. Second Edition. This curious work and valuable to all agriculturists, was the fruit of thirty years experience in the art of Draining, by Mr. Elkington, a Warwickshire Farmer, whose success had become so famous that Mr. Johnstone was appointed by the Board of Agriculture, and the Highland Society of Scotland, to examine and report the various processes adopted and Mr. Elkington was induced to communicate them to the public. Their importance is shown by a vote of Parliament in 1796 for authorizing the King to offer £1,000 to Mr. Elkington as an inducement for making known his discovery.

(4.) — Commentaire de S. J. Frontin, sur les aqueducs de Rome, Traduit avec le Texte en regard, Précèdé d'une notice sur Frontin, de Notions preliminaires sur les Poids, les mesures, les Monnaies, et la manière de Compter des Romains ; Suivi de la description des princepaux Aqueducs, construits, jusqu'á nos jours ; des lois ou Constitutions imperiales sur les aqueducs, et d'un Précis d' hydraulique, Avec trente Planches, Par J. Rondelet, Paris, 1820.

(5.) — The names of the Roman Aqueducts are taken from those of the River or Lake which supplies them, or from the Emperors who caused them to be constructed. In the 10th Section, Frontinus gives the following as the origin of the name of this. "It is called the Virgin (Virgo), because it was a young girl who showed some veins to a few soldiers who were in search of spring water. Those who dug followed these veins and found a great quantity, and there is a painting in a little temple erected close by the source representing this event." Rondelet's Translation, p. 19.

(6.) — Addition au Commentaire de S. J. Frontin sur les Aqueducs de Rome, &c. Par J. Rondelet, p. 19.

(7.) — A Fragment of a pipe forming part of this reversed syphon, is still preserved in the Museum at Lyons, and an instance of the Romans having laid pipes across the beds of rivers is given by M. Gautier, Architect, Engineer, &c. in his work called, *Traité de la construction des Chemins*. Published in 1778.

About 70 or 80 years ago he was directed by Mr. Pontchartrain Minister of State, to repair to Rochefort, to conduct spring water to the Port from the fountains of the City, which were supplied from a source, though quite insufficient for the City, in the neighbourhood. In his researches he discovered a good and copious source, at less than half a league, but on the other side of the river, the Charente. Many difficulties were presented, because at low water, vessels might ground upon the pipes and injure them. However, Mr. Gautier proposed to lay down two leaden pipes, to preserve a supply in case of accident to one, and to protect them by wooden frames in an effectual way against injury, should vessels lay upon the defence frames during low water. Mr. Begon, intendant of the Marine, approved the plan, but it was finally rejected.

"Some years after" says Mr. Gautier "when I had charge of the roads on the Rhone, and of many other works in the Province of Languedoc, and while at Arles, I heard that a vessel had cast anchor in the Rhone, opposite the City, to take some loading ; but when the commander wanted to sail again he could not raise his anchor. This fact attracted much attention, and many people went to witness the singular circumstance. The Captain, unwilling to lose his anchor, sent down a man, to find what was the matter. The diver reported that the anchor was hooked under something round, but he could not tell what it was. A capstan was applied to raise it, which succeeded. It brought up a leaden conduit pipe from the bottom of the Rhone, which crossed it from the City of Arles, towards Trinquetaillade, over a breadth of about 90 toises (575 feet), in a depth of 6 or 7 toises (42 feet), the deepest part of the

Rhone. I saw some pieces of this conduit of Lead, 5 or 6 inches in diameter, about 4 lines (one third of an inch) thick, in joints of 1 toise each soldered lengthwise, and covered by a strp or sheet of lead of the same thickness covering the first solder about 2 inches. The Conduit was soldered at the joints, 6 feet apart, by the same material, which made a swell at that distance. On each joint were these words in relief, C. CANTIUS POIHINUS. F. which was apparently the name of the maker or architect, who laid down the conduit pipe in the time of the Romans. I delayed not to inform Mr. Begon, at Rochefort, of this discovery, because he had always favored my project of conducting water along the bottom and across the Charente, which would not have been half so difficult as it had no doubt been, to lay one across the Rhone where this was found. Hence it may be believed, as I think now myself, that many things supposed now-a-days to be new and never to have been previously invented, may have been thought of long before, even in remote ages." Pages 129 and 130.

(8.) — An Historical account of Sub-ways in the British Metropolis, for the flow of pure water and Gas into the houses of the inhabitants without disturbing the pavement, including the projects in 1824 and 1825. By *John Williams*, the Patentee, Cornhill, London. London, 1828.

(9.) — An abstract of Mr. Thom's report and description is inserted in the *Mechanics Magazine*, Vol. 17 page 311, but I have not been able to find the pamphlet in English. It has been translated by Mr. Mallet into French, and is inserted with three plates in the *Annales des Ponts et Chaussées*, Vol. 1 of Memoirs and Documents, and from this the account is taken.

(10.) — *Annales des Ponts et Chaussées* 1 *Vol. Memoires et Documens*, *p*. 228.

(11.) — Essai Sur les Moyens de Conduice, d'Elever et de Distribuer les Eaux, Par M. Genieys, Ingenieur au corps royal des ponts et Chaussées, attaché au service de la Distribution des eaux dans Paris, — Paris 1829, page 153.

APPENDIX A.

Charlestown, May 16, 1834.

Gentlemen,

I had the pleasure of receiving your letter of June 16th, 1833 in due time, with a copy of the vote passed June 14th, at a meeting of the Directors of the Aqueduct Corporation. My engagements last year were such, that I could do nothing in the service of the company, except directing the survey of Jamaica Pond and the line of existing pipes from the pond to the city. During the winter I was occupied at Norfolk in Virginia, with my duties in the Dry Dock. I returned to Boston in March last, and have so far accomplished the object of the company as to report in part, pursuant to their vote.

The wishes of the Directors are as follows ; "To make an accurate survey of Jamaica Pond ; to estimate the capacities of the water rights of the Corporation, and if found sufficient to authorize a more extensive supply of water, so as to meet the wants of the inhabitants of the City of Boston, in the elevated part of the City ; to make accurate estimates of the expense of raising the water to a reservoir of sufficient height, either upon the hill adjacent to the pond, or to some other suitable elevation in the City of Boston, and to obtain all possible information essential to the interests of the Corporation, in reference to an extended use of the water, and an increase of income ; and to report as soon as may be."

It thus appears that the objects of the company are three, viz ; *First* to examine the resources of water and the means of increasing them ; *Second*, the best method of bringing the water to town, and *Third*, the best mode of distributing the water, and to what extent the inhabitants may enjoy the advantages of such supply.

From the short time I have been able to devote to this subject, I shall now only point out the state of the Pond, and the existing conduit pipes to conduct the water to the City, with the advantages of substituting better and larger pipes than those now in use.

The Pond was surveyed last fall with great care. In addition to the area when surveyed, I caused soundings to be taken at 3 feet depth, at convenient distances, to ascertain the area of the surface if the water was drawn down three feet below the level when surveyed. In the same way, and by soundings taken in the same manner, at 6, 9, and 12 feet below the survey. Similar surveys were made within the banks of the Pond, at successive levels of 3, 6 and 9 feet above the surface. From these measures the surface of the pond, when the survey was taken, is obtained, as well as the surface, as it may successively fall to 3, 6, 9, or 12 feet below, or rise 3, 6 or 9 feet above the actual survey. The result is given in the following table in which the number of each area is shown in the *First column ; the Second column* shows the aera of the depth or height of three feet successively, below or above the surveyed area of the pond : the *Third column* — the acres at each level, and the *Fourth column* the same area in square feet, which is the mean of an equal number of cubic feet of water at that level.

Table of superficial areas of Jamaica Pond at different levels.

No.		Acres.	Square feet.
1.	Area supposed 12 feet below survey,	50.316	2191764
2.	" 9 "	54.915	2392097
3.	" 6 "	58.90	2565684
4.	" 3 "	62.688	2730684
5.	Area of Pond when surveyed,	67.22	2928103
6.	" supposed 3 feet above survey,	71.445	3112144
7.	" 6 "	73.668	3208978
8.	" 9 "	76.443	3329857

From the foregoing table it will be easy to obtain the mean area, and of course, the quantity of water the pond contains, at each successive foot, between the highest and lowest state of the pond. Thus, taking the area when surveyed, for the mean depth of a foot, between six inches below and six inches above, we get 2,928,103 cubic feet of water. Multiplying this by 7.5, which is nearly the number of gallons in a cubic foot, we have 21,960,772 gallons, that is, one foot in depth of the pond at the level when surveyed, contains about 21 million of gallons. This result of the survey is very interesting, and will become important in considering the supply, and the means of securing and increasing it, in a future report.

Another important inquiry was requisite, even before proposing any alteration in the pipes for conducting the water to town, which was, to ascertain the fluctuations in the rise and fall of the water, independent of the quantity drawn from it by the conduit pipes. This has been furnished from the office, with sufficient details for our present purpose, and is presented in the following table, as delivered by Mr. Allen. The height of the water was taken with considerable accuracy, at or very near the end of each month during eleven years, by Mr. Allen — the superintendent. The depths of water are set down, as they were taken, in feet and inches, for every month during the last 11 years, and are all counted from the bottom of the trunk in which the water flows from the pond, and which is one foot above the bottom of the pipes.

The upper horizontal line in the Table shows the year, and the perpendicular column on the left, the month, when the measurses were taken. The first column on the right of 1833 shows the aggregate, and the second the mean depth, for each month ; the first horizontal line below December shows the aggregate, and the second the mean depth of each year. The means are set down in feet and decimals to three places.

Table of the height of water in Jamaica Pond for 11 years ending December, 1833.

Month.	1823	1824	1825	1826	1827	1828	1829	1830	1831	1832	1833	Total.	Mean.
January,	0.4½	3.11	3.9½	1.9¾	4.3½	7.8½	4.4	5.1¼	8.3½	6.9¾	6.3¼	52.8½	4.791
February,	0.4	6.	4.3¾	2.3¾	4.6½	8.4	5.2½	5.0½	8.1¼	7.4½	6.3¾	57.10	5.257
March,	3 0½	6.4¼	5.6½	3.6	6.11¼	8.6¾	6.6	6.	8.6	7.9	7.1	69.9¼	6.340
April,	4.	7.3½	5.4	3.9½	7.1	8.2	7.10½	6.2½	2.4¾	8.2½	7.7¼	74.11½	6.814
May,	4.10	6.9¾	4.11¼	3.5	7.9	8.5¼	7.2½	5.11	9.3	8.5	6.9	73.8¾	6.703
June,	4.7	6.0¼	4.1¼	2.10¼	7.0½	8.0¼	6.3¾	5.5½	8.5½	8.	6.1	66.11¼	6.085
July,	4.1½	4.8¾	3.2	2.3¼	6.	6.10¾	5.9	4.9½	7.6½	7 3½	5.1	57.7¾	5.241
August,	3.1	4.	2.7½	3.	5.2½	6.2	4.11	4.4¾	7.9½	6.9½	4.2	52.1¾	4.741
September,	2.9½	3.10	1.10½	3.2½	5.1	4.11¼	4.5	4.6	6.10	5.8½	3.5¼	46.7½	4.239
October,	2.0½	3.2¾	1.6½	3.3½	5.6½	4.5	3.8	4.2½	6.8	5.2½	3.0¾	42.10½	3.898
November,	1.6¼	2.9¾	0.11¾	3.6	6 5¾	4.	3.8¾	5.3¼	6.6	4.11½	2.10	42.7	3.871
December,	2.4½	3.2½	1.3¼	4.0¾	7.9¼	3.9½	4.3	7.2	6.2½	5.10¾	5.	51.5	4.674
Total,	33.1¼	58.2½	39.5¼	37.0¼	73.8¾	79.5¼	64.7	64.0¾	93.6½	82.5	63.8¼	689.2¾	
Mean,	2.759	4.857	3.286	3.085	6.137	6.619	5.382	5.338	7.795	6.868	5.307		5.221

The heights in the above table are all measured from the bottom of the trunk, opening to the box or cistern, from which the pipes lead the water, which is one foot above the lower side of the pipe. It is this level of one foot above the pipe, which is always referred to in speaking of the level of the pipe, when not otherwisc designated.

It appears from the Table that during the eleven years, the water was highest in April 1831, when it was 9 feet 4¾ inches, and that the highest year; the mean for the 12 months being 7.795 feet and the lowest 6 feet 2½ inches in December. The lowest year 1823, being only 0.4 inches in February, and the highest 4 feet 10 inches in May; the mean for the twelve months was 2.759 feet.

The highest month during the 11 years was April; the highest was 9 feet 4¾ inches in 1831; the lowest was 3 feet 9½ inches in 1826; and the mean of all the years for the month was 6.814 feet. The *lowest month* was *November*, the lowest 0.11¾ inches in 1825; the highest in 1831 6 feet 6 inches; and the mean for the eleven years was 3,871 feet, for the month.

The mean height of the pond, above the pipe, for the 132 observations during the eleven years, was 5.221 feet.

On the 27th, October 1822 the aqueduct stopped for want of water, that is, the level fell a few inches below the bottom of the trunk. It continued very low to January 1823, when it appears to have been, at the end of that month, the time when the observations were commenced, only 4½ inches, and in February 4 inches above the pipe. During the succeeding March it rose 2 feet 8½ inches, and has since been sufficiently high to furnish water at all times, for the last eleven years. The foregoing table furnishes sufficient authority for the belief, that more than ten times the quantity of water may be distributed in the town of Boston, than has been hitherto used. But I shall leave all further consideration relative to the pond, and an increased and permanent supply, to a special report upon this branch of the inquiry, and proceed to examine the existing state of the conduit pipes, as well as to recommend a total change of the present system.

CONDUIT PIPES.

The line of pipes from the pond to the old reservoir, and other branches, are very defective, and are necessarily subject to many injurious operations in renewing, separating, uniting, or stopping them, for conveyance of water, or for inspection and repair. I shall give a detailed description of the manner in which they are laid; the mode of some being united into one, or again divided from one into two, begining at the pond, and pursuing the line of pipes to the reservoir, from information obtained from Mr. Allen, the superintendent, and from Mr. George M. Dexter, Mr. Perham, and Mr. Ellison, who were employed to make the surveys and levels. A general plan of the route and changes is herewith sent to the Board of Directors.

The water is first drawn from the pond by two wooden pipes of 5 inches diameter each, for the distance of 184 feet and a fall of 12.50 feet from the surface of the pond when the survey was made, and 4.43 feet above the pipe, to the place marked A on the plan.

At this place, the two 5 inch pipes are united into a cast iron pipe 8 inches diameter, by a cast iron branch, as it is called, formed as shown on the sketch at A. This pipe extends 3,150 feet to a box near the edge of the marsh, where the iron main is changed into two *5s* again at B. in the same form, though reversed, as at A.

Thence the two 5s extend 5,764 feet to a box near the site of Wait's old mill on the creek. Here one of the 5 inch pipes divides into two of 3 inches diameter each, by means of what the workmen call saddles, in the following way. The end of the 5 inch log is stopped, and laid so as to leave about 2 feet between it, and the ends of the two 3 inch wooden pipes, stopped also. The end of a bent leaden tube is then inserted into the 5 inch, rising up and passing in the form of a basket handle, having its other end inserted into one of the 3 inch pipes. Another similar leaden pipe is let into the 5 inch pipe behind the first, and opens a communication with the second 3 inch log. These short connexions are made with leaden tubes, from 2½ to 3 inches diameter, and may be understood by figure C.

The other 5 inch pipe proceeds to a shed, marked D, 2,014 feet, where it is divided into two of 4 inches, with the directions of which it forms a very obtuse angle, and the connexion is made by a short strait wooden pipe laid so as nearly to divide the angle formed by the two lines, having the 5 inch opening into it about the middle in one side, and the 4's taking out on the opposite side, near the ends as seen at E. — These two 4 inch pipes proceed towards the Reservoir near Fort Hill in Boston.

At the creek F, after leaving the box C, the two 3s are turned together into a pipe or log of 7 inches diameter for about 100 feet, curving downwards from the marsh on one side, and rising again on the other when it is divided again into the two 3s. These crossing logs are large and at the end of that joint where the small pipes unite with it, there are two short tubes bored obliquely, perhaps two feet long, forming an acute angle at the axis of the 7 inch pipe, and being at the end so far apart as to admit one of the 3 inch pipes into each. The separation is made on the other side in a similar manner, as represented at F.

The pipe 5 inches diameter crosses the creek before reaching the shed, in the same way as the two 3 inch pipes, by one of 5 inches, and separates again into 2 of 3 inches at the shed, and thence they proceed with the two of 4 inches to Washington street.

From the shed to Mrs. Williams' house H. on the east side of Washington street is 3,264 feet, and the two 3 inch pipes and two of 4 proceed to near Mr. Wheeler's house I. on the north side of the street nearly opposite Mrs. Williams'. Here the 3s unite into one 5¾ inches diameter, by a cast iron branch like A, and crossing the street to Mrs. Williams', go down the east side of Washington street to a box J. near Mr. Chickering's 2,462 feet from Mrs. Williams'.

At this box the 5¾ inch branches into two 3s by joints of logs thus. A wooden pipe 5¾ inches diameter is laid across the street 30 feet long, at right angles with the line of pipes, into one side of which the leading pipe enters, and the two of 3 inch take out on the opposite side near the ends, and proceed one on each side of the street. These two proceed 2,140 feet to the head of Bridge street, where they are united into a 5 in a similar way as seen at J.

The two 4 inch pipes turn at Wheeler's down the west side of Washington street and go without change 4,642 feet to a box K. in Bridge street, when they are united into one of 5 inch, by a cast iron branch like A. The joints or bends in all these cases being at right angles.

It then proceeds along Front street to another box in front of the aqueduct shop L, when the 5 changes into two 4 inch pipes like J. one of which turns up Roe place and the other passes along Essex street, up Short street, turns down Bedford street to near Summer street church, (where a branch of 3 inches is taken off,) along Summer and up Purchase street to the Reservoir. After passing a short distance beyond the head of Russia wharf, the 5 inch pipe is changed into one of 1¼ in. diameter for about 3 feet, then to 4 again for about 75 feet where it is reduced to 3 inches for 6 feet, and thence in 4 inches to the Reservoir.

The reservoir was many years ago, at times, nearly full of water, but seems never to have been much used or relied upon, because, I presume, the conducting pipes from the Pond could not supply it, especially after the houses were furnished with water to such an extent, as to take all that could be given by the aqueduct. Now, and for many years, the communication has been cut off by what is called a gate, which will be described presently.

From the Pond to the Reservoir, along the line of aqueduct, is 25,613 feet or 4.85 miles. When the level was taken from the pond by Mr. Dexter, the surface was 4.43 above the pipes. Thence to the underpinning of Mrs. Williams' house, the fall was 47.07 feet in 14,376 feet ; thence the rise, to top of brick at the man hole or opening in the top of the arched covering of the Reservoir, was 34.45 feet in 11,237 feet. This leaves the top of the Reservoir 12.62 feet below surveyed surface of Pond; and deducting 4.43 feet, the pipe or bottom of trunk leading to it from the pond, is 8.19 feet above the top of the Reservoir, which being 21.58 feet deep, according to Mr. Ellison's level and survey, makes the bottom of Reservoir 34.20 feet below the surveyed surface of the pond, and 29.77 feet below the head of the pipes.

I have pursued the line of pipes from the Pond to Washington street, where it is divided into two branches, following only that which goes to the Reservoir, leaving the other and all small branches and distributing pipes of minor consequence in the immediate inquiry. Besides the numerous junctions and separations, changes of diameters, and angular forms of the connexions, along the whole line, there are other practices injurious to the speedy and adequate supply. I give them as described by Mr. Allen, who has been general superintendent of the aqueduct and distribution of the water for 17 years.

One of the evils of the present practice is putting in a *Gate*, as it is called. This operation is performed in the following manner. The *Gate* is a thin plate of iron about ⅛ of an inch thick, as wide as the diameter of the pipe where it is to be inserted, with the lower end formed semicircular to conform transversely with the lower half of the pipe. Above the horizontal diameter, the sides of the *gate* are perpendicular, rising several inches above the top of the interior diameter of the pipe, and tapering on the flat sides like a thin wedge to the lower end. The upper part of the *gate* is made narrower and thicker to serve for a handle, and to be struck with a hammer to drive it into its place. An opening is made in the earth and the log laid bare. The top is then dubbed off to a flat surface with an addice, and a hole from an ⅛ to ¼ of an inch is bored into the pipe, as near as may be, in the direction of the perpendicular diameter, from which, with a key hole saw, a slit is made in a transverse direction each way, from the hole to the side of the pipe at the ends of the horizontal diameter, and into this transverse slit the *gate* is driven, so that the convex end closes upon the concave lower side of the pipe. This effectually stops the passage of water.

Two of these gates are thus inserted about 200 or 300 feet apart, the intermediate space, in which a leak is suspected, being thus closed to the water flowing. The next thing is, the boring a hole about an inch diameter in the conduit about 10 inches or a foot distant from a second hole, one on each side of one of the gates. A tin tube, open at both ends, an inch diameter and about 7 feet long, is then inserted into the hole between the gates. A second tube, with a stop cock near the lower end, is let into the other hole, rising upwards parallel with the first, having a horizontal branch 10 inches or 1 foot long with a short piece turning downward over the upper open end of the first tube. On turning the cock, the water passes up the tube and falls into the one first described. If in this operation the water remains stationary in the tube between the gates, it indicates that there is no leakage between them, for the distance of 200 or 300 feet. But if the water sinks and it requires a constant supply through the tube with the stop cock, there is a leak somewhere in that section between the gates.

When it is thus ascertained that a leakage exists, to avoid the labour and delay of digging out the earth, for a distance of 200 or 300 feet, to find it, the following expedient is adopted. The superintendent goes along the line, and with a crow bar makes a hole in the earth over the conduit, to within a few inches or a foot of the wooden pipe, and generally in soft ground, not so near, and drives or pushes down a small pointed iron rod so as to strike into the wood ; then putting the upper end of the rod to his ear, he can almost invariably and plainly hear the waste stream running from the pipe. This audible discharge is more or less distinct, according as the leak is near or more remote, and practice has made it so effectual that Mr. Allen tells me he can without much trouble trace it, in a few trials, to the log or joint where it exists. When the trial is over the gate is withdrawn and the saw slit filled with wedges.

This very simple, ingenious and harmless proof by the iron rod has only been in use for a few years, and it is singular that it has been so often employed, that Mr. Allen has evidently suffered in his hearing, which he can account for in no other way, than by the rod being closely pressed into his ear so frequently as to injure it. The boring and sawing into the pipe and driving in the gate, must naturally leave splinters, indentations and roughness on the interior sides wherever it has been applied, and probably greater obstructions are left inside when the great holes are bored on each side of the gate. In every instance, more or less obstacles are created, and repeated operations of this kind must produce a most important retardation of the velocity.

Of all the serious defects of the present system of pipes, the greatest is that of the frequent branching of the pipes from one of large diameter to two of smaller size, and uniting two into one again, by the vicious mode of making the changes at right angles. There are between 30 and 40 changes of direction or angles of this kind, from the pond to the reservoir, almost all of which are at right angles, and where this is not the case the exceptions are but a little better. The whole of these should be avoided, and although the loss of head, of velocity, and consequently a diminution of supply are susceptible of calculation, the obstructions are so numerous and of such variety that no safe practical inference could result from it. How much water is lost by leakages on the way cannot be ascertained, but the moderate height to which water is delivered in town, to points supposed most elevated, with any continued supply, shows that great imperfections somewhere exist.

Water is well furnished to the Hon. P. C. Brooks, at the head of Pearl street, which is considered one of the highest points. It is received by a cock in his cellar, at a point about 5 feet below the foot path at the end of his house in High street, and 37.64 feet below the surface of the Pond.

Mr. T. B. Wales' is called another high point, in Winter street, and water is received into his cellar at a level of 10 feet below the side walk and 22.07 feet below the level of the Pond. The water is received here into a hogshead, at night only, and seldom rises above 2 feet.

Another point of supply is Mr. Fox's house in Hollis street. Here water is delivered at a point 43.37 below the Pond, and it has been supposed that this was a high point from the uncertainty of keeping up a supply. Perhaps the water is too much drawn off, before reaching these places, by other customers, but there is no doubt that more than double the quantity might be brought to the City, if the two first pipes of 5 inches diameter, which take it from the pond, were continued without changing and abrupt deviations.

Such appear to me the obvious defects of the actual state of the wooden pipes, and the manner in which they are laid, that I would advise the company to abandon the present works, so far as regards the main conduit to town, and substitute an uninterrupted cast iron pipe with proper branches to discharge into reservoirs. I shall therefore proceed to state my reasons for the satisfaction of the Directors.

CAST IRON PIPES.

Many Philosophers and Engineers have investigated the principles upon which water flows through pipes, open canals and rivers, and have given various formulas for calculating the velocity and discharge, in all cases suited to practical occasions for use. Prony has given two very safe formulas for pipes; — the most simple and which he recommends for practice is,

Where $\begin{cases} V=48.5254\sqrt{DS}, \text{ as reduced to English feet,} \\ V=\text{the velocity in feet per second,} \\ D=\text{diameter of the pipe in feet,} \\ S=\frac{H}{L}, \end{cases}$

H is the head or height, from the surface of the pond or source, at the entrance, to the level of the axis of the pipe at the lower end, when it discharges into the air, or to the surface of the water above the mouth of the pipe, and L=the whole length of the pipe. The measures are all in feet.

Having used this formula in numerous calculations, upon pipes of various diameters, in the course of the inquiry, I shall place the result in the form of a table, and proceed to illustrate some principles to guide in adopting a plan for works of this kind. A loss of velocity is produced in water flowing through a pipe, by its friction along the interior boundary, and as this boundary or interior periphery varies as the diameter, while the area or transverse section varies as the square of the diameter, it follows that two pipes of given and equal diameter, will not discharge so much water in a given time, as one wherein the transverse section is equal in area to that of both the others, of the same length and under the same head; because the two will have a greater rubbing surface than the single pipe.

The two 5 inch pipes which take water from the Pond, pass through the arch way under the road 184 feet to their union with the 8 inch iron one, and the head or fall from the surface of the Pond to the place of junction is 12.50 feet. If the ends were not united into the large pipe, but were open into the air, each pipe would discharge 4008 cubic feet an hour, while a pipe 7.071 inches diameter, equal to both the 5s in section, would discharge 9428 cubic feet per hour; that is, 1412 feet mere than the other two. This difference is owing to the difference of friction mentioned in the preceding section, and to the viscosity of the water. The same disparity exists in greater lengths and less heads, though the discharges will be less, by both pipes. The whole distance to the reservoir is 25,613 feet=4.85 miles, and a pipe 5 inches in diameter, entering near the bottom, and the water therein standing above the mouth, and 10 feet belo w the level of the pond, would discharge 303,8 cubic feet in an hour=7,291 feet or 54,684 gallons a day. That of 7.071 inches, under the same circumstances, would discharge 720 feet an hour, and during the day 17,280 feet=129,600 gallons, or 20,232 gallons more than both the 5 inch pipes, and if one continuous cast iron pipe 8 inches in diameter were laid in a judicious manner, it would discharge into the reservoir, wherein the water stood 10 feet below the pond 23,610,5 feet or 177,078 gallons a day.

These observations show the importance of Hydraulic principles, where works of this kind are to be established, or any other constructions relating to water-works. But another very essential consideration is that of economy. Suppose the two pipes to be half an inch thick, cast and delivered along the line at 5 cents the pound and taking cast iron at 4 cubic inches to the pound. One foot of the 5 inch would cost $1,30 and the two together $2,60. In the whole distance, 4.85 miles, the cost of the two would be $66,580, while that of the single pipe 7.071 inches in diameter, would be $1,783 a foot or $45,659, for the whole length. Thus a saving of $20,921 would be obtained by adopting the large single pipe, instead of the other two, whose joint areas of section are equal to that of the large one. The ratio of discharge in favour of the single pipe is as 1.185 to 1, and of expense as 1 to 1.457. The advantages therefore on the side of a single one are as 1.72 to 1.

Two small pipes should, therefore, never be applied instead of a large single one, within ordinary limits of practice, unless local and peculiar circumstances render it necessary. A pipe of 6.60 inches diameter would afford the same discharge as the two of 5 inches, and would cost only $1,67 a foot, or $42,970 for the whole length, or $23,789, less than two smaller ones.

I shall give a table of the effective discharges of pipes of different diameters, under different heads and of different lengths, that the Directors may be able to form a pretty correct opinion of the size, they may think it policy to adopt, and afterwards present some remarks which may influence their decision. The *first* column shows the diameter in inches; the *second* the velocity in feet per second; the *third* the area of section in feet; the *fourth* discharge in cubic feet per second. *Fifth* discharge per minute — *Sixth* in an hour — *Seventh* in a day, and the *eighth* the gallons, obtained by multiplying the feet by 7.5.

It should be observed that a deduction must be made from the velocity and discharge given in the table, on account of an unavoidable deviation from a right line, in which the conduit must be laid. There will be some perpendicular, as well as horizontal bends and especially in turning corners and streets in town. The main line will not be subject to much retardation from the Pond to the City. Whenever an abrupt turn or a right angle is formed, a curved pipe, with a section made a little larger, will be expedient.

TABLE OF DIAMETERS AND DISCHARGES OF DIFFERENT PIPES.

Head 12.50 feet and Length 184 feet.

Diam	Velocity.	Area.	Second,	Minute.	Hour.	Day.	Gallons
3	6,32479	,04909	0,31046	18,6276	1117,656	16823,744	126172
4	7,30324	,08727	0,63733	38,2398	2294,388	55065,312	412987
5	8,16527	,13635	1,11334	66,8004	4008,024	96192,576	721440
6	8,9383	,19636	1,75512	105,3072	6318,432	151642,368	1137315
7	9,5740	,26725	2,55860	153,5160	9210,960	221063,040	1657972
8.	10,2838	,34906	3,60521	216,3126	12978,716	311490,144	2336175

Head 25 feet and Length 25,613 feet.

3	,75817	,04908	,037217	2,2330	133,981	3214,857	24105
4	,87546	,08726	,076399	4,5839	275,034	6600,874	49500
5	,97880	,13635	,13346	8,0079	480,456	11530,944	86475
6	1,07200	,19636	,21000	12,6001	756,007	18144,117	136070
7	1,15789	,26725	,30944	18,5664	1113,984	26735,616	200512
8	1,23784	,34906	,43208	25,9248	1555,488	37331,712	279982
9	1,31292	,44174	,57994	34,7964	2087,784	50106,816	376196
10	1,38394	,54541	,75482	45,2892	2717,352	65216,448	489120
11	1,45149	,65994	,95790	57,4740	3448,440	82762,560	620715
12	1,51603	,78539	1,19068	71,4408	4286,448	102874,752	771556
13	1,57790	,92174	1,4545	87,270	5236,20	125668,80	942510
14	1,63552	1,06900	1,7505	105,030	6301,80	151243,20	1134336
15	1,69500	1,22717	2,0801	124,809	7488,54	179724,96	1347930

Head 20 feet, same length.

3	,67799		,03322	1,9968	119,812	2875,478	21562
4	,78287		,06832	4,0991	245,948	6902,761	44265
5	,87528		,11934	7,1604	429,624	10310,976	77325
6	,95880		,18783	11,2699	676,195	16228,685	121710
7	1,05660		,27678	16,6068	996,408	23913,792	179347
8	1,10718		,38648	23,1888	1391,328	33391,872	250432
9	1,17336		,51873	31,1238	1867,428	44818,272	336135
10	1,23786		,67514	40,5084	2430,504	58332,096	437470
11	1,29827		,85678	51,4068	3084,408	74025,792	555187
12	1,35599		1,06500	63,9008	3834,——	92016,	690120
13	1,41137		1,3009	78,054	4683,24	112397,76	842977
14	1,46465		1,5657	93,942	5636,52	135276,48	1014560
15	1,51605		1,8604	111,624	6697,44	160738,56	1205535

Head 15 feet, same length.

3	,58715		,02882	1,7293	103,759	2090,221	15675
4	,67799		,05917	3,5499	212,997	5111,942	38332
5	,75801		,10335	6,2010	372,060	8929.440	66767
6	,83037		,16267	9,7600	582,601	14054,429	105405
7	,89691		,23970	14,3820	862,920	20710,080	155325
8	,95885		,33470	20,0820	1204,920	28918,080	216885
9	1,01703		,44923	26,9538	1617,228	38813,472	291097
10	1,07202		,58469	35,0814	2104,884	50517,216	378877
11	1,12563		,74285	44,5710	2674.26	64182,240	481365
12	1,17433		,92231	55,3386	3320,316	79687,584	597652
13	1,22228		1,1266	67,596	4055,76	97338,24	730035
14	1,26842		1,3560	81,360	4881,66	117158,40	878685
15	1,31294		1,6112	96,672	5800,32	139207,68	1044052

Head* 10 *feet — and, length* 25613 *feet..

Diam	Velocity	Second.	Minute.	Hour.	Day.	Gallons.
3	,47941	,02353	1,4119	84,719	2033,251	15247
4	,55358	,04831	2,8985	173,909	4173,811	31297
5	,61892	,08439	5,0633	303,800	7291,209	54682
6	,67797	,13282	7,9690	478,141	11475,389	86062
7	,74939	,20027	12,0162	720,972	17303.328	129772
8	,78289	,27331	16,3986	983,916	23613,984	176097
9	,83038	,36680	21,9080	1314,480	31547,520	236602
10	,87529	,47739	28,6434	1718,604	41246,496	309345
11	,91801	,60583	36,3498	2180,988	52343,712	392572
12	,95885	,75306	45,1836	2711,016	65064,384	487980
13	,99989	,9199	55,194	3311,64	79479,36	596092
14	1,03565	1,1071	66,426	3985,56	95653,44	717397
15	1,07201	1,3155	78,930	4735,80	113659,20	852442

By the preceding table is shown the capacity of pipes for discharging water into the Reservoir, near Purchase street, on the South side of Fort Hill. The pipes are supposed to discharge into the Reservoir near the bottom, and the water to stand at the height of 25, 20, 15, or 10 feet below the level of the Pond; or in the Reservoir successively, at 9,20; 14,20 ; 19,20; and 24,20 feet depth. The first part of the Table is confined to the distance of 184 feet from the Pond, with a fall of 12,50 feet, to show the comparative effective discharge of various pipes, from 3 to 8 inches diameter inclusive, with that of the 2 of 5 inches now placed in that distance. The comparison shows the disadvantage, under many circumstances, of laying small pipes, when a single one of little larger diameter can be applied instead of them. In this case, the pipe of 8 inches diameter will discharge the same quantity during a day, as the two of 5 inches, the two of 4 inches, and six sevenths of that of 3 inches diameter, although the aggregate diameters of the five pipes would be 21 inches, while the single pipe nearly equal to them all, is only 8 inches. The daily discharge is added in gallons, as many people may better understand the comparison in that measure.

It will be convenient now to present a view of the relative cost of pipes of different capacity, which will become useful in deciding upon the diameter to be adopted. The usual lengths of the joints are 9 feet, and half an inch is sufficient thickness for that to be recommended here within the preceeding table. Four cubic inches of cast iron is the general allowance for a pound, in such estimates. Pipes half an inch thick, and of 9 to 15 inches diameter would cost from 4 to 5 cents the pound, delivered along the line, nearly upon the spot where they are to be laid.

TABLE OF DIAMETERS AND COST OF CAST IRON PIPES.

Diameter.	Pounds.	Cost per foot.	Per Mile.	Cost of 4.85 Miles.
5 inches,	25,90	$1,30 at 5 cts.	$6864,00	$33296,00
6 "	30,60	1,53	8078,00	39180,00
7 "	35,34	1,77	9346,00	45326,00
8 "	40,05	2,00	10560,00	51216,00
9 "	44,76	2,24	11827,00	57361,00
10 "	49,47	2,47	13041,00	63251,00
11 "	54,18	2,70	14256,00	69141,00
12 "	58,89	2,94	15523,00	75287,00
13 "	63,60	3,18	16790,00	81431,00
14 "	68,31	3,42	18057,00	87576,00
15 "	73,02	3,66	19324,00	93721,00

The following are the relative heights of some points in town compared with that of the Pond at the time of the survey.

1. First step at street going up to the State House, marked on end, 13,99 ft. above Pond.
2. Floor of State House, - - 46,61 do.
3. Mark on North Gate post of Mr. Gardner Green's house, about 2 or 3 inches above foot walk, 16,38 below Pond.
4. Bottom of column of Tremont House, - - - - - 8,61 do.
5. Mark at east post of S. Appleton's house, Beacon street, about 6 inches above foot walk, - - Level with Pond.
6. Mark on Stone foundation of Dr. Keep's back yard in Beacon st. about 1 foot above foot walk and 10 feet below the gateway. - Level do.
7. Mark on Basement story of house No. 6, Park street, 2 inches above foot walk, - - - Level do.
8. Mark on underpinning of Mr. Jackson's house, Somerset st. No. 21, - - - - - - Level do.
9. Mark at corner of Belknap and Myrtle street, Provision Store, about 1 foot above foot walk, - Level do.
10. Mark N. E. corner of Hancock and Myrtle street, about 1 foot above foot walk and 2 feet from corner, - - - - - - Level do.
11. Mark on underpinning of Mr. Lemuel Pope's house, corner of Bowdoin and Derne street, upper side, - - - - - Level do.
12. Mark on top of foundation of Iron fence, corner of Mrs. Blake's house, Bowdoin square, corner of Square and Cambridge st. 8 inches above foot walk, - 28,19 ft. below Pond.

13.	Upper step of Purchase Street Meeting house, - - -	33,54	below Pond.
14.	Upper step of Mr. Topliff's front door in Oliver street, - -	9,70	above Pond.
15.	Highest point of Fort Hill near centre of circular inclosure, -	11,94	do.
16.	Mark on South edge Stone near head of Gibbs' lane, - -	Level with	Pond.
17.	Mark on Stone of Mr. Waterston's yard corner of Oliver and High streets, near corner of edge Stone, - - - - - -	Level	do.
18.	Mark on octagonal stone post near E. Reynold's house, corner of High and Hamilton streets, about 15 feet below the corner, - - - - - -	Level	do.
19.	Mark on North end of Gun house, Fort Hill, 10 bricks below top of window, about level with the street in a line with that end of the house, - - - -	Level	do.
20.	Top of plinth of columns of Market house, - - - -	45,55	below Pond.
21.	Coping of Reservoir in North Square, - - - - -	23,96	do.
22.	Highest point on Copp's Hill, -	0,70	above Pond.
23.	Coping of Dry Dock in Charlestown Navy Yard, - - -	49,70	below Pond.

I had intended to offer some considerations for substituting a large iron pipe instead of those now existing; but shall defer it until better opportunities offer for ascertaining whether a greater supply of water can be obtained than what the Pond now furnishes. You will perceive by what has been done, that almost all the town can now be furnished from the Pond, except the highest point on Beacon Hill round the State House, and in order that the water may be extended to the highest points with facility, a large conduit pipe should be laid. I have no doubt that a pipe 12 inches in diameter, will supply five or six times the persons who now take it, with more constancy than heretofore. Further remarks as to the supply, manner of laying the main, Reservoirs in the City, and other particulars referred to in the vote of the Directors, will be given in a few days.

With great regard, your obedient servant,

L. BALDWIN.

To Henry Codman, Esq.
Thomas A. Dexter, Esq.
Committee of Directors of Aqueduct Corporation.

APPENDIX B.

Boston, August 28, 1834.

Col. L. Baldwin,

Dear Sir,

Herewith I send you an account of my analysis of nine specimens of Lake water, from the vicinity of Boston, undertaken at your request last month. The bottles were all marked with letters of the alphabet and their examination was taken up in the same regular order. The sources from which the water was obtained are to me unknown ; thus I am able to furnish you with an account of their several merits without being in any way liable to imputation of bias in my judgment.

The objects to be accomplished in a chemical examination of this water are, to determine which of the specimens submitted to me are the most free from foreign matter, and best adapted to the ordinary purposes of life. With these objects in view the specimens were examined with great care, and compared with each other as to freedom from colour, flocculi of animal, vegetable or mineral matter and animalculi. Then their specific gravity, as compared with pure distilled water at 60° F, was taken in a specific gravity bottle containing 1000 grs. After which, 5000 grs. of the water was distilled and when reduced to a small bulk, was removed from the retort, and the evaporation of the remaining water was finished under a bell glass over a surface of concentrated sulphuric acid, which, by absorbing the water without heat, is less liable to effect any decomposition of the residue. The remaining solid matter, which was contained in a watch glass of known weight, was then submitted to a very delicate balance and its weight determined. A portion of it was then incinerated in a platina capsule, and its nature ascertained by tests.

The water was next examined by tests calculated to detect the nature of the foreign matters they were liable to contain in solution.

Below, you have a statement copied from my Laboratory notes, which will give you the processes and the results of my researches.

I hope to be able to furnish you with analyses of the different well waters of the City, by which it will appear that we are in the habit of drinking several salts in considerable quantities, which must have deleterious effects on the human constitution. I will now only observe that one of the best specimens of clear well water from Bowdoin street, yields 3.6 grs. of the salts, Sulphate of Lime, Muriate of Soda, and Muriate of Lime, to the pound of water. The well is 30 feet deep and is situate high up on the side of the hill. I have also examined the water of the well at my residence No. 11, Hanover street. The well is 40 feet deep and the water stands about 10 feet from the surface. This water gives 7.5 grains of the above salts to the pound of water; although the taste of the water is not unpleasant to those who have been accustomed to it. It must however be prejudicial to the health, when we consider that several pounds of it are drank by each person in the course of a day.

I have made examinations of the water of several other wells in the City, but have not kept notes of the quantities of matter they contain. I am satisfied, however, that there are wells, whose water is infinitely worse than those I have mentioned, which have the reputation of being good water although they contain noxious matter.

From conversation I have held with several eminent physicians of the City, I have learned as the result of their observations that the well water of the City is prejudicial to the health, and that where dyspeptic persons have been able to change their drink from well to aqueduct or rain water, they have always found their symptoms abate and have often been entirely cured.

There are many persons upon whom the well water of Boston acts very unpleasantly, making them sick at the stomach almost as soon as it is drank, in most persons it produces constipation of the bowels and many other concomitant or consequent symptoms of diseased functions.

It is much to be desired that good water should be supplied to the City so as to reach every dwelling and supply every person.

The advantages of Lake water consist in its being entirely free from Mineral salts, and its softness renders it appropriate for washing, while its freedom from all deleterious matters renders it desirable for drink and for cooking. It being well known that infusions made with pure water are much stronger than those made with well water, it will appear that Lake water is better adapted for making tea and coffee than well water.

Allow me to express the high consideration with which I have the honour to be, your obedient servant,

CHARLES T. JACKSON.

A Chemical Examination of nine specimens of Lake water from the vicinity of Boston. July 1st, 1834.

The bottles were marked A, B, C, D, E, F, G, H, and I.

A. The water in this bottle contains a few minute flocculi, but is otherwise transparent and colorless. It contains a few oval shaped animalculi, with antennae and a tail of a minute size, which move with great velocity by starts through the liquid. Specific Gravity =1,003 pure water being =1.

5000 grains distilled and the evaporation finished in a watch glass over sulphuric acid covered with a bell glass there remained a brown residue =0.12 gr. which when burned gave odour of vegetable matter, and left a grey ash consisting of lime and silex =0.01 grains.

1st. The water was now tested with a solution of nitrate of silver in pure water. No precipitate took place until the test tube was exposed to sun light when the solution changed to a brown colour, and a black precipitate subsided to the bottom of the glass. This indicates organic vegetable matter.

2d. Tested with oxalate of ammonia. No precipitate; hence contains *no* salt of lime.

3d. Tested with Muriate of Barytes. No precipitate; hence does not contain any Sulphate.

4th. Tested with Ferro-cyanate of Potash. No precipitate; hence does not contain any salt of iron.

5th. Tested with Hydro-Sulphate of Ammonia. No precipitate.

6th. Tested with lime water. No precipitate; hence does not contain any carbonic acid.

7th. Tested with a solution of soap in alcohol. No precipitate takes place, and when shaken it froths well; hence is well adapted for washing.

B. The water in this bottle is of a brown colour and contains animalculi, like those in A. Specific gravity =1.002.

5000 grains distilled and evaporated to dryness gave 0.25 grains of brown vegetable matter.

Tested in the same manner as A, it gave signs of vegetable organic matter, but no mineral salts. When this water is filtered through charcoal it becomes colorless.

C. The water in this bottle is transparent and free from color; has a few animalculi like those in A. Specific gravity = 1,000.

Tested like A it gives a trace of vegetable matter, but no mineral salts.

It washes well and gives no precipitate with tincture of soap, 5000 grains evaporated to dryness gives 0.02 grs brown vegetable matter.

D. The water in this bottle is free from sediment, transparent and colorless. It contains a few animalculi like those in A. Specific gravity = 1.001.

Tested like A with similar results. 5000 grains of the water evaporated to dryness leave 0.15 grs. vegetable matter.

E. Water clear, transparent and colorless; has a few animalculi. Specific gravity = 1.001. 5000 grs. evaporated to dryness leave 0.1 gr. brown matter.

Tested as A similar results were obtained.

F. Clear, transparent and colorless. No animalculi. Specific gravity = 1.0002. 5000 grs. evaporated to dryness, leave 0.2 gr. brown matter.

Tested as A same results.

G. Clear, transparent and colorless; has a few flocculi. No animalculi. Specific gravity = 1.0005. 5000 grs. evaporated to dryness leave 0.1 gr. vegetable matter.

Tested as A with similar results.

*H. Has a slight tint of brown and contains a few floc-

*Another specimen of H. taken from the outlet of the lake was examined, which was free from color, flocculi and animalculi. Specific gravity same as above, but yields somewhat less vegetable matter.

culi and animalculi. Specific gravity =1.0005. 5000 gr evaporated to dryness gave 0.3 gr. Tested as A with same results.

I. — Clear, transparent and colorless. No flocculi or animalculi. Specific gravity = 1.0002. 5000 grs. evaporated to dryness yields 0.15 grs. vegetable matter. Tested as A with similar results.

From the foregoing researches it will appear that the water in bottles A, C, D, E, F, G, H, and I, is sufficiently pure for the ordinary uses of life. B is too much charged with vegetable matter to be desirable. C, D, F, G, and I, are preferable and are nearly pure; the quantity of vegetable matter contained being extremely minute, sensible only to delicate tests. This vegetable matter is common in all lake water in which there grow aquatic plants, and its quantity is greater near the shores of the lake than in deep water.

The water in B, I suppose, must have been taken from a small lake with a peat or boggy bottom, in which grew many aquatic plants, and that the lake had not free circulation by an outlet and supply from springs.

The animalcules noticed in the water are extremely common in all water exposed to the air at this season of the year, and are probably the larvae of some small insect like the musquito. The water in the middle of the lakes will probably be found free from them, as they breed in the shallow warm water near the shore. It will also be less liable to be contaminated by vegetable and animal matter.

I may now be permitted to state in conclusion, that the lake waters here examined, with the exception of B, are all sufficiently pure for the supply of water to the City, and that the water is wholesome and pleasant to drink; well adapted for cooking and washing. It is also recommended particularly to brewers, for the making of beer or porter, as it not only extracts better the virtues of the hops and grain employed, but enters more readily into fermentation than hard well water. For the same reasons it is more appropriate in making bread and all infusions and decoctions of herbs. It is also better for the supply of ships going on long voyages, as it soon purifies itself in the cask, and is then absolutely free from all unpleasant smell and taste, provided the casks are charred on their inner surface, so as not to add anything soluble in water. It is better for the manufacture of soda and other artificial mineral waters. It is better adapted for bleacheries, dye houses, chemical laboratories and manufactories, Tanneries, &c. Its advantages are so great over well water, that even if an abundant supply of the latter could be obtained by boring, still it would be desirable to bring lake water from the vicinity, on account of its greater purity and adaptation to our wants.

Your obedient serv't,

CHARLES T. JACKSON.

APPENDIX C.

Waltham, Sept. 17, 1834.

L. Baldwin, Esq.

Dear Sir,

I have looked over the analysis made for us by Dr. J. F. Dana in the year 1820, but can find nothing relating to the water of Charles River.

I called on Dr S. L. Dana last evening, to see if he had any facts relating to this subject. He says that he once analyzed the water, but did not preserve the minutes; he recollects that the principal impurities in addition to the vegetable matter in solution, were carbonate of iron and sulphate of lime.

Charles River water is soft and excellent for washing. Goods dried from it, however, become yellow; we were obliged therefore, at some thousands of dollars expense, to bring spring water in pipes to our bleachery for our last washings.

Would not the impurities which the river collects in passing so many manufacturing establishments be an objection to its use in families?

In addition to the waste liquors from paper mills, bleacheries, dye houses, and other works, it receives its daily contributions from every person employed in the establishments. In a very large stream these additions could never be discovered, but Charles River in a dry season is quite a moderate sized stream. Whether it had any sensible effect on the water or not, the idea of drinking it, could not be very pleasant to those who were acquainted with the facts.

With much esteem, I am, dear sir, very sincerely yours,

EBEN HOBBS, Jr.

Boston, Nov. 21, 1834.

Col. Baldwin,

Dear Sir,

Since I gave in my report on the lake and river waters in the vicinity of Boston, I learned through your letter from Dr. Hobbs, that Dr. Dana had detected sulphate of lime and carbonate of iron in the water of Charles River, which substances were not found by me in the water marked F, in my report. Aware of the just reputation of Dr. Dana as a chemist, I was anxious to satisfy myself of the truth of his observations by a second analysis of the water in question. The specimen which I had already examined was regarded as an unfair one, and on that account, I obtained, through your kindness, a fresh supply, free from all objections as to the locality from whence it was taken.

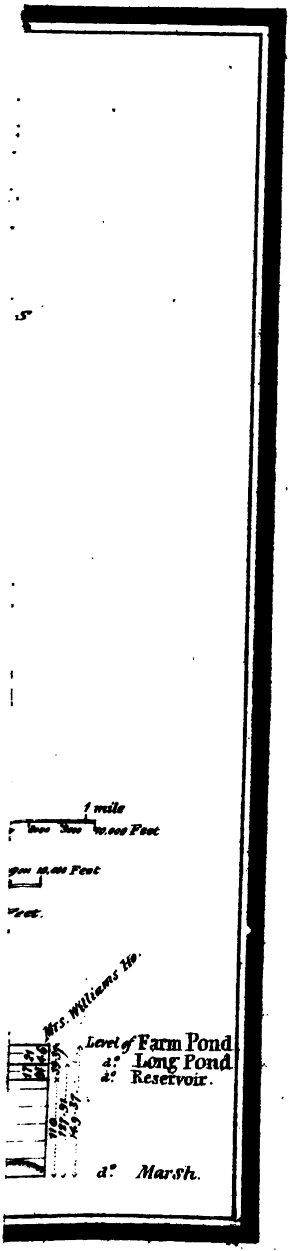
This water was then marked F 2d, and was examined like those formerly analyzed. Its specific gravity was 1.0004.

10000 grs. distilled and the evaporation finished in a porcelain capsule. The residue dissolved in dilute nitric acid without effervesence. The solution was then tested by oxalate of ammonia, when a slight precipitate took place of oxalate of lime. Tested with a solution of muriate of barytes, a white precipitate of sulphate of barytes took place. Tested by liquid ammonia for iron no precipitate took place, but when the vegetable organic matter was incinerated and the ashes dissolved in dilute acid and treated with hydro sulphate of ammonia, a trace of iron is easily obtained. From this circumstance, it appears that the oxide of iron must have existed in combination with the vegetable organic matter, or that it prevented its precipitation by the ordinary means.

The water does then contain a trace of sulphate of lime, but I am not decided whether the oxide of iron exists in the state of carbonate, or in combination with the organic matter. It will require that a very large quantity of water should be operated upon to settle this question. Please enter this note, in whole or in part, as you may see fit, in my report which you have undertaken to publish in your appendix.

Your obedient servant,

CHARLES T. JACKSON.


1 mile
Mrs. Williams Ho.
Level of Farm Pond
d° Long Pond
d° Reservoir.
d° Marsh.